ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR

FINAL REPORT

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EXECUTIVE SUMMARY

This study identifies the remedial and mitigative measures for achieving various proposed uses in specified areas for Hamilton Harbour and develops a framework for valuing the benefits associated with the resulting improvements in water quality and recreational activities. Past and present uses of Hamilton Harbour were inventoried and baseline data was collected. The uses included:

- recreational boating
- fishing
- environmental interpretation and outdoor education
- shipping and navigation
- wastewater receiving body
- industrial water supply
- other recreational uses such as ice boating and skating

Future uses of the Harbour waters, using as much available data as possible, include all of the above plus swimming and water sports. The preferred end use favored by the Stakeholders and used in this study was a self-sustaining edible fishery.

Existing pollution loadings to Hamilton Harbour have been identified and quantified according to their sources: a) point sources such as municipal sewage treatment plants and industrial discharges; and b) non-point sources such as combined sewer overflows, storm water runoff and Cootes Paradise. Remedial measures considered for Hamilton Harbour include point source and non-point source control. Implementation of nitrification, sand filtration, dual point injection, and rerouting of the effluent to Lake Ontario are considered for Hamilton and Burlington sewage treatment plants. Housekeeping changes including rerouting some discharges to the municipal sewer system are considered for industrial sources. Best management practices for agriculture, control of combined sewer overflows and control ponds for new subdivisions are considered for non-point sources.

Mitigative measures considered for Hamilton Harbour include: oxygen injection, beach construction and habitat enhancement for the fishery. Specific fishery measures include creation of islands in the Grindstone Creek delta, and addition of rubble and other underwater features along the Lax property and Burlington shores. The measures considered for Cootes Paradise include diking/cell separation to enhance pike and bass reproduction and to control bottom sediment erosion, and dredging to minimize phosphorus release.

Both remedial and mitigative measures are evaluated in terms of costs (capital, operating and maintenance), their effectiveness for pollutant reduction and enhancement of harbour uses. The effect of the above remedial and mitigating measures upon water quality were considered quantitatively and incorporated into a cost effectiveness analysis. The effect of iron, alum and lime addition, nitrification, carp control, shore-line grooming, and of the above noted remedial and mitigative measures upon the various end uses were considered qualitatively.

The cost effectiveness analysis is presented in two forms. The costs of implementation of four alternative sets of remedial and mitigative measures are related to the improvement in hypolimnetic dissolved oxygen and to the change in water clarity and the associated change in littoral fish habitat. Then the costs of implementation of another set of mitigating and remedial measures are related to the potential yield of Northern Pike and Largemouth Bass.

The cost-effectiveness analysis can be used to evaluate where major changes in water quality occur for a small increment in costs. The results indicate that improvement in hypolimnetic dissolved oxygen is quite inelastic until substantive control of phosphorus and ammonia has occurred. Nitrification in the Hamilton Sewage Treatment Plant can be achieved at relatively small cost, but its impact upon oxygen resources is small due to the large effects caused by phosphorus inputs and sediment oxygen consumption. Nitrification has the most substantive effect upon potential ammonia toxicity in the Harbour. Phosphorus control by implementation of sand filtration and dual injection has a large impact upon oxygen resources but also a large increment in cost. Mitigating measures for enhancing the fishery are estimated to have a much larger effect upon fish production than control of point sources at a fraction of the cost.

These remedial and mitigative measures may have a large effect upon toxic substances in the Harbour. Their impact and the effect of measures such as alum, iron, lime or oxygen injection were not considered due to the lack of necessary data. Their impact upon substances such as medical radionuclides do not require consideration because the risk to humans is substantially below regulatory limits.

Two different approaches (a benefit-cost assessment, and an analysis of economic impacts) were used to assess the economic effects of the nine control measures identified as being cost effective in promoting a self-sustaining warm water fishery. The benefit-cost assessment compared the increase in economic benefits (or consumer surplus) accruing to

Hamilton area residents with the costs of implementing the control measures. Two types of economic benefits were identified: use value, and non-use or intrinsic value.

The estimate of use value used in this study is based on increases in recreational fishing and swimming only. No estimates were available of potential increases in other activities and, therefore, no use value could be assumed for them. Similarly, it was not possible to estimate the increase in consumer surplus which would accrue to current recreationalists as a result of improved Harbour conditions. The estimates of use value used in the analysis may, therefore, underestimate the actual total. Assuming implementation of all nine control measures, the estimates of use value are:

- $0.13 million per year from increased recreational fishing
- $5.50 million per year from swimming

Non-use value, assuming implementation of the entire sequence of control measures, is approximately $20 million per year. Total economic value benefits exceed the costs by approximately $12.4 million after implementation of all nine measures. Net economic benefits maybe positive after implementing the first eight measures depending on assumptions regarding non-use value. The results of the benefit-cost assessment are highly dependent on estimates of non-use value.

Economic impacts generated by increased fishing and swimming as a result of improved conditions in the Harbour are small. Capital expenditures for all nine measures results in the creation of 1,300 jobs and an added income to the Hamilton area of $118 million during the construction phase. Impacts generated by operating and maintenance expenditures are small.

Significant information gaps, linkage uncertainties and assumptions used throughout this document were expanded upon. A sensitivity analysis was undertaken varying some of the key assumptions used in the benefit-cost assessment. The analysis is based on variations of three key factors: estimates of non-use values, use estimates for fishing and swimming and the time horizon for converting capital costs into annual values. Alteration of assumptions regarding use value and amortization of capital costs has relatively little impact on the results of the benefit-cost assessment. This is not the case for non-use values. Three different estimates were assumed for these values, all of which are supported by the literature. The resulting net economic benefits ranged from extremely large, to negative.

A sensitivity analysis of the relative importance of biological, chemical, engineering, and economic and information/data gaps would be useful but was not undertaken in this study. For water quality, the development and validation of models for eutrophication and toxic substances are required. In addition, data characterizing the levels of toxics in various biota and their physiochemical form in various geochemical reservoirs are required. For swimming, established in this study as a key end use, selection of the most appropriate water quality parameters, background data characterizing loads and receiving water concentrations, and modelling analysis of response of the harbour to control are essential. In support of this work, the physical hydrodynamics of the harbour need further research. For fishing, scenarios assessed in this study must be viewed with caution because these scenarios are an experiment; whether the fishery of the harbour will respond biologically is an experiment which has not been duplicated in other case histories.

The results of the benefit-cost assessment indicate that there is an economic basis for improving water conditions in Hamilton Harbour. As noted, these results are highly dependent on estimates of non-use value, which should be regarded as preliminary. The proposed control measures entail a significant financial investment and as such, warrant more refined supporting data upon which to base a decision supporting their implementation. Such data could be obtained by a survey of Hamilton-area residents. Additional recommendations include the need for data in the areas of: recreational uses, more refined costs for remedial and mitigative measures, point and non-point source loadings and eutrophication modelling.

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1.0 INTRODUCTION

1.1 General

1.1.1 - Purpose of Study

The purpose of this study is to evaluate and integrate the relevant biological, chemical, social and economic data and information in order to determine a cost/benefit framework for the Hamilton Harbour Remedial Action Plan.

An initiation meeting took place on September 1, 1987, at the Canada Centre for Inland Waters located in Burlington, Ontario. A detailed list of those present at the meeting is presented in Appendix A.

The major conclusions agreed to at this meeting include that:

a) the **preferred end use** for this study is a **self-sustaining edible warm water fishery**

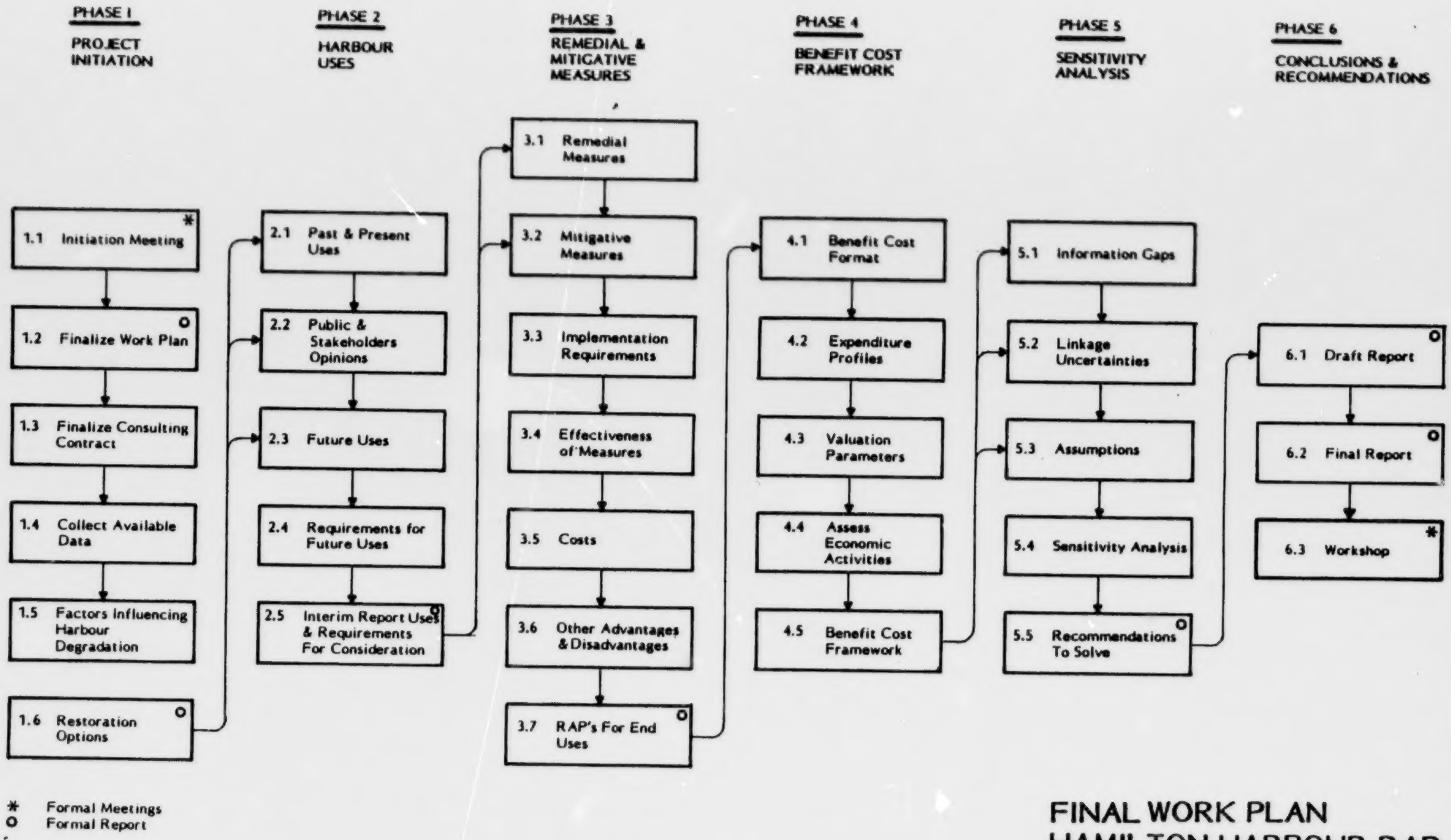
b) the **focus of** the study will be on **water quality** only

c) the study will develop a **detailed cost/benefit** framework for a specific end use. Other end uses can then be related to it with the recognition that there will be much less detail involved with these other end uses.

1.1.2 - Work Plan

The final work plan (Figure 1) agreed upon is divided into 6 phases which are:

Phase 1 - Project Initiation - This phase covers the normal project start-up requirements such as finalizing the consulting agreement, collecting and evaluating all readily available existing data and finalizing the detailed work program. However, this Phase also includes an initial evaluation, in consert with the Remedial Action Plan Writing Team for Hamilton Harbour of the factors influencing Harbour degradation.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FINAL WORK PLAN
HAMILTON HARBOUR RAP

87-08-04

FIGURE NO. 1
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Phase 2 - Harbour Uses - This phase documents past and present uses and develops user/market information related to possible future uses. The water quality criteria and other factors are assessed in order to meet the requirements of viable future uses of the Harbour.

Phase 3 - Remedial and Mitigative Measures - During this phase the details of the remedial measures, the mitigative measures, the implementation requirements such as scheduling, etc., are developed. Cost estimates are prepared for each, their effectiveness/efficiency is evaluated and the advantages/disadvantages of each are noted. An assessment of cost effectiveness of mitigative measures for a self-sustaining fishery is undertaken.

Phase 4 - Benefit Cost Analysis - During this phase the monetary and non-monetary benefits of the anticipated increased uses of the restored Harbour will be developed.

Two different approaches were used to assess the effects of the control measures which would be cost effective in promoting a self-sustaining warm water fishery:

- a benefit-cost assessment
- analysis of economic impacts

Phase 5 - Sensitivity Analysis - Significant information gaps were identified throughout the assignment which cannot be adequately addressed due to schedule and budget constraints. Further it is likely that significant assumptions will have to be made regarding biophysical linkages between water quality and restored uses. This Report will document these assumptions and present to the extent practical a sensitivity analysis of the impact of such uncertainties.

Phase 6 - Conclusions and Recommendations - The results of all studies including conclusions and recommendations are documented in this Draft Report. Following review and comment a Final Report will be submitted after receipt of all comments on the draft.

Desired end uses expressed by the Stakeholders(4) include; fishing (warm water fishery, eventually cold water fishery), boating, water body contact sports, swimming, shipping, industrial intake and discharge, wildlife habitat, and as an educational resource. As agreed upon at the initiation meeting the application measures are to be focussed towards the establishment of a warm water sustainable edible fishery.

1.2 Analytical Data

1.2.1 - Sources of Data

It is to be acknowledged here that much of the information supplied comes from Interim Report of the Writing Team for the Hamilton Harbour Remedial Action Plan[2]. Additional sources of analytical data utilized for this study are listed in the reference portion of this Section.

1.2.2 - Parameters

Factors contributing to the degradation of water quality in Hamilton Harbour which must be addressed include:

Chemical

- chemical oxygen demand
- ammonia
- total kjeldahl nitrogen
- nitrate
- nitrite
- phosphorus
- heavy metals

Biological

- BOD (biochemical oxygen demand)
- fish (carp)
- bacteria
- toxic organics
- algae

Physical

- filling
- suspended solids
- turbidity
- near shore environments
- vegetation
- currents

1.2.3 - Data Precision

Water and sediment quality data should be analyzed with the knowledge that quality greatly depends on sampling locations within the harbour. An example is Windermere Basin where contamination is much higher than elsewhere in the harbour.

Concentrations of contaminants vary seasonally and from year to year reflecting constant physical/chemical changes in the harbour basin. (e.g. Manganese concentration in deeper water is higher in the summer/late fall due to higher reducing conditions of the hypolimnion).

Problems inherent in the data set include:

- unknown behaviour of the contaminants in the sediments on the water column
- the paucity of data available for calculations of loadings
- lack of information on the effect of trace metals and organics on the biota of the harbour
- the quality assurance of the data supplied

The chemical quality of Hamilton Harbour water and bottom sediments are outlined in Tables 1.1 and 1.2 respectively.

1.3 Guidelines and Standards

1.3.1 - Discussion

Guidelines and standards published by the Ontario Ministry of the Environment are presented with Hamilton Harbour Data in Tables 1.1 and 1.2. In many cases, effluent from point sources are or will shortly be meeting Ministry guidelines6). Significant technological improvements to sources will have to be implemented to improve effluent quality. Even by improving point source effluent to meet Ministry standards the overall loading to the harbour will mean that the quality of harbour waters will probably not meet Ministry objectives. The reason for this dilemma is that there are many contributing non-point sources of contaminants, high levels of existing contamination in the harbour and the possibility of sediment contribution to contamination within the water column. A global approach may be needed for the

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
HAMILTON HARBOUR WATER QUALITY DATA
TABLE 1.1

PARAMETER	HARBOUR WATER QUALITY *		PROVINCIAL WATER QUALITY OBJECTIVES FOR PROTECTION OF AQUATIC LIFE AND RECREATION **
STANDARD (mg\L except pH)	Mean Values - 1983 unless noted otherwise		
NH3-N (un-ionized ammonia)	1.13		0.02
TKN (total kjeldahl nitrogen)	1.76		
NO2-N (nitrite)	0.17		1.0 Drinking Water
NO3-N (nitrate)	1.41		10.0 Objectives
Total Phenols	0.056		0.001
FRP (fraction reactive phosphates)	0.014		
Si (dissolved reactive silica)	0.46	(1980)	
BOD (biological oxygen demand)	3.09		
COD (chemical oxygen demand)	15.7	(1979)	
TOC (total organic carbon)	3.66		
DOC (filtered organic carbon)	3.22		
Conductivity	424		
Alkalinity	104	(1980)	
pH	7.83	(1980)	6.5 - 8.5
SO4 (sulphate)	51.2		
Chlorine	50.4		0.002 warm water fishery
Turbidity	2.65	(1980)	
SS (Suspended Solids)	4.68	(1980)	
Chlorophyl **a**	14.5		
METALS (µg\L)	Mean Values - 1982 unless noted otherwise	Range	
Cu Copper	7	7 - 40	5
Ni Nickel	5	1 - 17	25
Zn Zinc	20	2 - 116	30
Cd Cadmium	0.2	0.2 - 0.9	0.2
Pb Lead	5	3 - 31	25
Fe Iron	200	20 - 1000	300
Mn Manganese	39	17 - 880	-
Hg Mercury (Filtered)	0.07	0.03- 0.26	0.2
As Arsenic	1		100
Cr Chromium	0.66	-	100
Note: Cyanide was tested for but was always below the detection limit (5 µg\L)			
ORGANICS (µg\L)	Median - 1982 values	Maximum	
Total PCB	< 0.020	0.030	0.001
α-BHC	0.0045	0.006	
β-BHC	< 0.001	0.003	
γ-BHC	0.003	0.059	0.010 ***
Endosulfan Sulfate	< 0.004	0.004	
Heptachlor Epoxide	< 0.001	0.001	0.001 ***
Oxychlordane	0.002	0.004	
HCB	< 0.001	0.004	
Aldrin	not detected		0.001
heptachlor	not detected		0.001
Mirex	not detected		0.001
DDT	not detected		0.003
alpha and gamma chlordane	not detected		0.06
dieldrin	not detected		0.001
methoxychlor	not detected		0.04
endosulfan I & II	not detected		0.003
endrin	not detected		0.002

Note: * Ministry of the Environment, August 1985, Hamilton Harbour Technical Summary and General Management Options, Great Lakes Section, Water Resources Branch.

** Ministry of the Environment, May 1984, Water Management Goals, Policies, Objectives and Implementation Procedures

*** Poulton, D.J., 1987, Trace Contaminant Status of Hamilton Harbour, Journal of Great Lakes Research 13(2): 193-201, International Association of Great Lakes Research, 1987.

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
HAMILTON HARBOUR SEDIMENT QUALITY DATA
TABLE 1.2

PARAMETER	HARBOUR SEDIMENT QUALITY *		MOE GUIDELINES FOR DREDGED SEDIMENT DISPOSAL IN OPEN WATER ***
STANDARD (milligrams\g unless noted otherwise)	Mean Values - 1980 unless noted otherwise		
BOD (biochemical oxygen demand)	2.60 mg\g	(1977)	-
SOD (sediment oxygen demand)	150.00 mg\g	(1977)	-
NH3-N (ammonia)	10.00	(1977)	100
TKN (total kjeldahl nitrogen)	3.50 mg\g		2
Total Phenols	3.20 mg\g		-
Acid Extract P	2.30 mg\g	(1975)	-
Ether Extract (oil and grease)	7.60 mg\g	(1977)	1.50
METALS (micrograms\gram unless noted otherwise)	Mean Values - 1980 unless noted otherwise		
Fe Iron	68 mg\g		10
Cu Copper	130		25
Cr Chromium	204		25
Ni Nickel	44		25
Zn Zinc	2700		100
Pb Lead	310		50
Cd Cadmium	5.70		1
Mn Manganese	1900		-
Hg Mercury	0.30		0.30
Co Cobalt	10		50
As Arsenic	-		8
ORGANICS (milligrams\g)	Median - 1982 values	Range	
PCB's and Pesticides			
Total PCB	0.020	0.020-1.270	0.05
α-BHC	0.001	0.001-0.006	
β-BHC	** 0.002	0.013	
α-chlordane	0.002	0.002-0.018	
τ-chlordane	0.0045	0.002-0.020	
aldrin	** 0.001	0.001	
oxychlordane	** 0.002	0.008	
O,P-DDT	** 0.005	0.010	
P,P-DDE	** 0.001	0.009	
HCB	** 0.001	0.004	
Polynuclear aromatic hydrocarbons(PAH's)			
Fluoranthene		0.0019-0.0043	
Perylene		0.0012-0.0097	
Benzo(k)fluoranthene		0.0011-0.0090	
Benzo(a)pyrene		0.0012-0.0111	
Benzo(g,h,i)perylene		0.0016-0.0086	
Indene(1,2,3 cd)pyrene		0.0011-0.0097	

Note: * Ministry of the Environment, August 1985, Hamilton Harbour Technical Summary and General Management Options, Great Lakes Section, Water Resources Branch.

** Poulton, D.J., 1987, Trace Contaminant Status of Hamilton Harbour, Journal of Great Lakes Research 13(2): 193-201, International Association of Great Lakes Research, 1987.

*** Bersaud, D. and Wilkins, W.D., Evaluating Construction Activities Impacting on Water Resources, Ministry of the Environment, Water Resources Branch, 1976.

various point sources in order to meet water quality guidelines in Hamilton Harbour, an overstressed basin.

Non-point sources contributing to the pollution of harbour waters include overland runoff during heavy rainfall and introduction of contaminants to the harbour by creeks and streams. The actual loadings by all non-point sources are unknown. The ultimate sources of pollutants which enter the drainage system are widespread and include phosphorus and pesticides from farming practices, increased erosion of sediments from construction and farming, and also the likelihood of toxic materials from past or present industrial uses.

1.4 Analysis of Data

1.4.1 - Point Sources of Contaminants

The loadings of materials from the various sources are summarized in Table 1.3.

1.4.1.1 - Hamilton and Burlington Sewage Treatment Plants

Sewage treatment plants are the main source of ammonia (NH_3- N) to the harbour. Ammonia causes high oxygen depletion within the water column and results in toxicity to fish and aquatic life.

The treatment plants are also a major source of phosphorus which is a limiting nutrient for the growth of algae. Severe algal growth would also cause high oxygen depletion which endangers aquatic life.

Other pollutants contributed by the sewage treatment plants include;

- BOD (biochemical oxygen demand)
- COD (chemical oxygen demand)
- polyaromatic hydrocarbons (PAH's)
- trace metals
- sulphur
- bacteria
- suspended solids

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
SOURCE LOADINGS
TABLE 1.3

PARAMETER	SOURCE HAMILTON SEWAGE TREATMENT PLANT 1977	1982	1983	1985	BURLINGTON SEWAGE TREATMENT PLANT 1977	1982	1983	1985	STELCO 1977	1982	1983	1985	DOFASCO 1977	1982	1983	1985	Source COMBINED SEWER OVERFLOWS 1977	1982	1983	1985	CREEKS Redhill 1977	Grindstone 1977	Cootes Paradise 1977	Creeks 1985	STORM WATER RUNOFF Hamilton 1977	Burlington 1977	1983	1985	TOTAL LOADINGS ** 1977	1982	1983	1985
Flow (10^3 cu. m/d)	212.0	290.0	-	307.0	56.0	78.1	-	71.0	2.5	-46.0	-	1002.0	-1.0	-13.0	-	786.0	-	-	-	-	83.4	82.7	315.0	-	31.0	40.2	-	-	-	-	-	-
STANDARD (kg/day)																																
BOD	5340.0	3750.0	4300.0	-	510.0	650.0	-	-	3670.0	5900.0	-	-	2640.0	780.0	-	-	-	-	-	-	1080.0	300.0	2300.0	-	210.0	220.0	-	-	19730.0	-	-	-
COD	20803.0	-	-	-	3400.0	-	-	-	26400.0	17500.0	-	-	30300.0	29000.0	-	-	-	-	-	-	6400.0	2150.0	13600.0	-	1600.0	1100.0	-	-	105050.0	-	-	-
SS	11600.0	4530.0	3730.0	-	910.0	720.0	-	-	46000.0	14500.0	-	-	30200.0	15200.0	-	-	-	-	-	-	3500.0	3300.0	30000.0	-	1200.0	1300.0	-	-	144030.0	-	-	-
TDS	135000.0	-	-	-	-	-	-	-	250000.0	-	-	-	-	-	-	-	-	-	-	-	96000.0	-	11000.0	-	7600.0	-	-	-	567600.0	-	-	-
TOC	7870.0	-	-	-	2300.0	-	-	-	705.0	-	-	-	2430.0	-	-	-	-	-	-	-	1700.0	1000.0	1700.0	-	530.0	430.0	-	-	18787.0	-	-	-
Phosphorus	325.0	333.0	320.0	299.0	45.0	75.0	-	67.0	70.0	-	-	-	35.0	0.0	-	-	-	-	-	70.0	57.0	75.0	140.0	80.0	13.0	3.0	-	5.0	741.0	-	-	600.0
TIP	192.0	283.0	-	-	37.0	40.0	-	-	0.0	-	-	-	0.0	-	-	-	-	-	-	-	12.0	10.0	20.0	-	10.0	1.0	-	-	281.0	-	-	-
NH3-N	10600.0	6200.0	6890.0	3300.0	460.0	160.0	-	630.0	1730.0	910.0	-	156.0	1750.0	1540.0	-	390.0	-	-	-	200.0	70.0	3.0	130.0	-	80.0	2.0	-	-	14033.0	-	-	7876.0
NO3-N	860.0	-	-	-	140.0	-	-	-	-	-	-	-	70.0	-	-	-	-	-	-	-	93.0	105.0	130.0	-	30.0	132.0	-	-	1689.0	-	-	-
Cl	39700.0	-	-	-	45400.0	-	-	-	6200.0	-	-	-	14000.0	-	-	-	-	-	-	-	6260.0	11500.0	17000.0	-	990.0	6960.0	-	-	147510.0	-	-	-
Phenol	0.0	-	-	-	0.0	-	-	-	170.0	260.0	-	-	25.0	40.0	-	-	-	-	-	-	0.2	0.7	0.0	-	1.0	0.1	-	-	197.1	-	-	-
Cyanide	0.0	-	-	-	0.0	-	-	-	1050.0	190.0	-	-	40.0	20.0	-	-	-	-	-	-	0.0	0.0	0.0	-	1.0	0.0	-	-	1090.0	-	-	-
METALS (kg/day)																																
Fe	210.0	230.0	125.0	-	7.0	6.1	6.1	-	21500.0	6300.0	-	-	13000.0	4020.0	-	-	-	-	-	-	10.0	12.0	1100.0	-	90.0	2.0	-	-	36475.0	-	-	-
Cu	18.0	5.5	5.6	-	1.0	3.7	1.7	-	110.0	8.0	83.0	-	23.0	0.0	1.0	-	-	-	-	-	0.0	0.0	7.6	-	0.7	0.6	-	-	162.3	-	-	-
Pb	10.1	7.0	1.2	-	0.0	2.0	0.2	-	15.0	37.0	12.0	-	5.1	5.0	0.0	-	-	-	-	-	1.3	1.1	10.0	-	1.2	1.1	-	-	49.1	-	-	-
Zn	85.0	33.0	37.5	-	5.0	7.0	0.6	-	1061.0	214.0	56.0	-	116.0	72.0	60.0	-	-	-	-	-	2.0	2.0	25.0	-	5.0	1.0	-	-	1261.0	-	-	-
Cd	1.2	0.3	0.030	-	0.0	0.2	0.3	-	0.0	-	-	-	1.0	-	-	-	-	-	-	-	0.4	0.1	1.0	-	0.1	0.2	-	-	3.1	-	-	-
Mn	33.0	24.0	-	-	5.0	0.5	0.0	-	263.0	-	-	-	220.0	-	-	-	-	-	-	-	0.0	0.0	60.0	-	0.0	2.0	-	-	737.0	-	-	-
Cr	36.0	9.0	5.5	-	1.0	1.0	0.4	-	50.0	27.0	46.0	-	90.0	9.0	3.0	-	-	-	-	-	1.7	1.7	7.0	-	1.1	0.0	-	-	193.1	-	-	-
As	-	-	0.038	-	-	-	-	-	5.0	-	-	-	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.0	-	-	-
Ni	13.0	13.0	10.1	-	-	1.0	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.0	-	-	-
Al	-	-	107.7	-																												
Hg	-	-	0.008	-																												
Se	-	-	0.1	-																												
ORGANICS (kg/year)																																
PCB's & Pesticides																																
Total PCB	-	-	4.6	-	-	-	0.9	-																					-	-	-	-
alpha-BHC	-	-	0.5	-	-	-	0.1	-																					-	-	-	-
beta-BHC	-	-	0.6	-	-	-	0.1	-																					-	-	-	-
gamma-BHC(Lindane)	-	-	1.0	-	-	-	0.4	-																					-	-	-	-
alpha-chlordane	-	-	0.2	-	-	-	0.1	-																					-	-	-	-
gamma-chlordane	-	-	0.3	-	-	-	0.1	-																					-	-	-	-
Mirex	-	-	1.9	-	-	-	0.6	-																					-	-	-	-
DDT & Derivatives	-	-	1.5	-	-	-	0.1	-																					-	-	-	-
HCB	-	-	1.4	-	-	-	1.1	-																					-	-	-	-
Dieldrin	-	-	-	-	-	-	0.1	-																					-	-	-	-
Oxychlordane	-	-	-	-	-	-	-	-																					-	-	-	-
Heptachlor Epoxide	-	-	-	-	-	-	-	-																					-	-	-	-
Endosulfan Sulfate	-	-	-	-	-	-	-	-																					-	-	-	-
Pentachlorophenol	-	-	11.0	-	-	-	-	-																					-	-	-	-
Polynuclear Aromat Hydrocarbons (PAH)																																
Napthalene	-	-	20.3	-	-	-	-	-																					-	-	-	-
Acenapthylene	-	-	4.1	-	-	-	-	-																					-	-	-	-
Fluorene	-	-	19.0	-	-	-	-	-																					-	-	-	-
Fluoranthene	-	-	65.7	-	-	-	-	-																					-	-	-	-
Pyrene	-	-	84.0	-	-	-	-	-																					-	-	-	-
Benzo(a)pyrene	-	-	69.4	-	-	-	-	-																					-	-	-	-
Polynuclear Hetero cyclic Compounds																																
Carbazole	-	-	43.0	-	-	-	-	-																					-	-	-	-
Dibenzofuran	-	-	12.0	-	-	-	-	-																					-	-	-	-

Sources of Data include:
1. "Hamilton Harbour Technical Summary and General Management Options", MOE, August 1985 - see reference 1 Appendix B-1
2. "Interim Report of the Writing Team for the Hamilton Harbour Remedial Action Plan", February 1987 - see reference 2 Appendix B-1
3. Zukovs G., Rush R.J., Gamble M. (Canviro Consultants Ltd.), 1984 - see reference 11 Appendix B-1

** Total Loadings from available sources only

1.4.1.2 - Steel Industries - Stelco and Dofasco

Stelco and Dofasco are major sources of Fe, other heavy metals, phenols, cyanide and suspended solids[1].

Other materials contributed by the steel mills include;

- COD (chemical oxygen demand)
- sulphur
- ammonia

1.4.2 - Non-Point Sources of Contaminants

1.4.2.1 - Sanitary/Storm Sewer Overflow

One Sanitary/Storm Sewer overflow during heavy rainfall is believed to be a major source of ammonia, phosphorus, bacteria, BOD and suspended solids to the harbour.

The Storm Sewer overflows (twenty six in total) may be a source of PCB's and organochlorines[1] which are transported from local industry.

1.4.2.2 - Runoff/Streams

Surface runoff and streams are a major source of suspended solids which create turbidity within the basin and are also believed to be carrying nutrients such as phosphorus.

1.4.2.3 - Landfill/Leachate

It has been assumed that leachate from landfills in the southwest area of the harbour is either controlled or represents a minor part of the contaminant problem (Personal communications Bill Snodgrass) . This assumption could possibly be premature as leachate could be a source of PCB's, trace organics, polyaromatic hydrocarbons (PAH's) and lead.

1.5 References

1. Ontario Ministry of the Environment August 1985, **Hamilton Harbour Technical Summary and General Management Options**, Great Lakes Section, Water Resources Branch

2. Rodgers G.K., Cairns V., Marsden J., Murphy T., Selby C., Simser L., Vogt J. February 1987, **Interim Report of the Writing Team for the Hamilton Harbour Remedial Action Plan, Towards a Comprehensive Remedial Action Plan for Hamilton Harbour**

3. Cairns V. October 1986, **Remedial Actions to Restore the Hamilton Harbour Fishery - Draft**, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, Burlington, Ontario

4. Land Use Research Associates. September 8 1986, **Interim Report: Hamilton Harbour's Water Quality: The Stakeholder's Proposals**

5. Remedial Options Work Group August 25, 1978, **Remedial Options for Contaminated Sediments in the Great Lakes Basin,** Report of the Remedial Options Work Group to the Sediment Subcommittee

6. Rodgers G.K. **Development of a Strategy for Rehabilitation of Hamilton Harbour,** National Water Research Institute, Environment Canada, Canada Centre for Inland Waters, Burlington Ontario; Paper for presentation at the 34th Ontario Industrial Waste Conference

7. Ontaro Ministry of the Environment May 1984, **Water Management Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment**, November 1978, Revised May 1984

8. Leppard S.M. January 1987, **Dialogue on Hamilton Harbour**, Issue #1 January 1987, Hamilton Harbour Stakeholder Group

9. Personal communication with G.K. Rodgers including table of IJC objectives entitled Great Lakes Water Quality Agreement Specific Objectives - Basis and Rationale

10. Poulton, D.J., 1987. **Trace Contaminant Status of Hamilton Harbour.** Journal of Great Lakes Research, 13(2): 193-201, International Association of Great Lakes Research, 1987.

11. Zukovs G., Rush R.J., Gamble M., (Canviro Consultants Ltd.), 1984, **Removal of Hazardous Contaminants in the Hamilton Water Pollution Control Plant,** Proceedings Technology Transfer Conference # 5, November 27 & 28, 1984, Part 1 General Research, Organized by The Research Advisory Committee, Sponsored by the Policy and Planning Branch, Ontario Ministry of the Environment.

2.0 HARBOUR USES

2.1 Introduction

The purpose of Section 2 of this study is to document past and present uses of the Harbour, collect information on users and patterns of use, and develop water quality and other requirements which support the proposed future uses of the Harbour. Data collected in this section will provide input into the benefit cost framework for evaluation of remedial and mitigative measures to improve water quality, aesthetics and fish and wildlife habitat. It will provide baseline data on present use of the Harbour and both quantitative and qualitative data which will be used to project future use, costs and benefits of remedial actions in the future phases of the project.

Work in this section has progressed according to the final work plan as outlined in Section 1. Tasks in this section include:

- an inventory of existing users of the harbour, patterns of use, levels of use and projected use;
- confirmation of uses defined by the stakeholders;
- identification of projected future uses and the extent to which each category of use will be affected by the remedial action plans to improve water quality; and
- outline water quality and other factors required to support the projected future uses.

In addition to the assessment of Harbour Uses, work in this section included collection of both qualitative and quantitative data on the projected uses. These will provide a basis for projecting future benefits of Harbour uses in the benefit cost analysis.

Data was collected from existing sources where they existed, but primarily through interviews with user groups. The interviews were conducted using an interview guide. This guide was designed to standardize the format of the interview while allowing the collection of additional qualitative information which will provide inputs in later parts of the project.

2.2 Past and Present Harbour Uses

An inventory of the past and present uses of Hamilton Harbour was conducted and estimates of the present level of use were calculated. Where possible, existing data were used; however, most activity groups did not keep strict records concerning facility and program provision either on number of users or the level of use. As a result, the major source of information for much of this analysis were interviews with representatives of the providers of activities, facilities and programs. In some cases, verbal information on participation in activities was acquired through this method and where records were not kept, estimates of such factors as frequency of participation were solicited. The following sections summarize the level of use of the Harbour for recreational boating, fishing, environmental interpretation and outdoor education, shipping and navigation, waste water reception and industrial water supply.

2.2.1 - Recreational Boating

Data on recreational boating in Hamilton Harbour was collected primarily through interviews with officials of boating clubs, the Hamilton Harbour Commission and the municipal parks and recreation departments in Hamilton and Burlington (see list in Appendix B). A series of questions in an Interview Guide was created as the survey instrument (see Appendix C). This survey was supported by additional information from existing documents (see Appendix D). Estimates of the level of use of the existing facilities were made using capacity estimating methods developed in the Ontario Recreation Supply Inventory (ORSI).

2.2.1.1 - Facilities

A number of types of facilities were inventoried including slips, moorings, ramps, docks and dry sailing storage. Slips and moorings are used primarily by large sail and power boats while ramps are used to launch mostly smaller boats, the majority of which are power boats. A summary of the results of the facility inventory is presented in Table 2.1.

The largest single provider of recreational boating facilities is the Hamilton Harbour Commission which has space for 480 boats at its marina. It has one ramp located to the west of the marina. Other facility providers include the Hamilton Yacht Club, Macdonald Marine and the Burlington Sailing and Boating Club1). Two other facilities

TABLE 2.1

INVENTORY OF RECREATIONAL BOATING FACILITIES IN HAMILTON HARBOUR

Location	Slips	Moorings	Ramps	Docks	Dry Sailing	Type of Boats	Trends
Hamilton Harbour Commission	230	250	1	x	(a)	90% Sail 10% Power	Last added slips over 10 years ago
Hamilton Yacht Club	135	-	(b)	x	70	70% Sail 80% Power	No change
West Leander Boat Club	-	-	-	x	(g)	35% rowing sculls 5 coach boats	Stable
Macassa Bay Yacht Club	105	-	(c)	x	-	50% Sail 50% Power	n/a
Macdonald Marine	50	-	-	x	-	60% Sail 40% Power	n/a
Burlington Sailing and Boating Club/Lasalle Park	217	-	2	x	-	95% Sail 5% Power	Opened 1973
Pier 4 Park	-	-	1 (h)	2	(d)		

a) boats used for sailing school

b) 3 hoists

c) cranes

d) boathouse operated by scouts (canoes) and sailing school (portable trailer) operated by YMCA

e) incorporates existing Macassa Bay Yacht Club and Macdonald Marine

f) capacity not available

g) 50 boats and 5 instructor boats

n/a not available

h) gravel ramp only

which utilize the sculls and sailing dinghies but no slips or moorings. A second gravel boat ramp is located at Pier 4 Park.

Location of these facilities is identified in Figure 2.1. All but one of the recreational boating facilities inventoried are located in the extreme south-west corner of the harbour between Pier 7 and the Hamilton Island landfill site. The Burlington Sailing and Boating Club La Salle Park Marina is the only marina facility located on the north shore of the bay.

In total there are 737 slips, 250 moorings and 70 dry sail spaces available in the harbour. Of these, approximately 70% are occupied by sail boats and 30% by power boats. Four ramps are also provided, two in Hamilton and two in Burlington.

The above facilities are utilized primarily for sailing, power boating and rowing. Canoeing and kayaking also take place in the harbour. A boat house at Pier 4 Park stores canoes for the Boy Scouts and canoes and kayaks are launched from Princess Point. However, the extent of these activities is not known since no records are kept by individual recreationists and these small boats do not require large facilities which can be inventoried.

2.2.1.2 - Programs

Learn to sail programs and rowing are the only boating programs offered which use the harbour directly (Power Squadron programs use existing boats not specific course boats and are not included to avoid double counting those boats). Programs offered by the various sailing clubs are listed in Table 2.2.

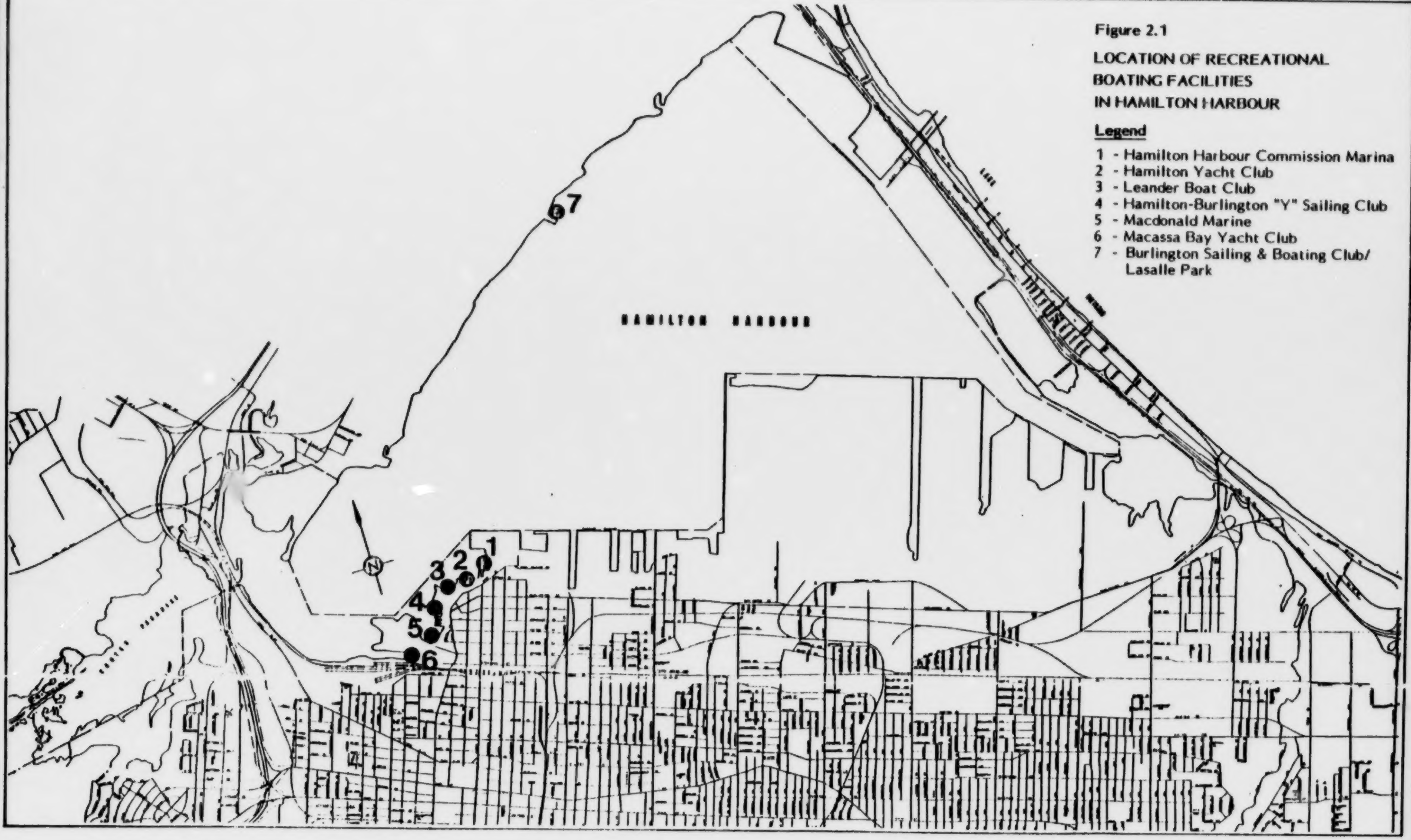
HAMILTON HARBOUR
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Figure 2.1

LOCATION OF RECREATIONAL
BOATING FACILITIES
IN HAMILTON HARBOUR

Legend

1 - Hamilton Harbour Commission Marina
2 - Hamilton Yacht Club
3 - Leander Boat Club
4 - Hamilton-Burlington "Y" Sailing Club
5 - Macdonald Marine
6 - Macassa Bay Yacht Club
7 - Burlington Sailing & Boating Club/
Lasalle Park

TABLE 2.2

NUMBER OF PERSONS ENROLLED IN PROGRAMS OFFERED IN HAMILTON HARBOUR

Learn to Sail Programs

Offered by:	Adult	Junior	Other	Total
Hamilton Harbour Commission	1,500	--	1,000	2,500
Hamilton Yacht Club	50	50	--	100
Burlington Sailing and Boating Club	120	40	--	160
YMCA Sailing School	90	--	--	90
Total:	**1,760**	**90**	**1,000**	**2,850**
Rowing Programs				
West Leander Boat Club	50*	80**	--	130

* *Adult rowers are trained and coached but there is not a specific program length as in most sailing programs.*

** *These are high school programs offered as an after school sport.*

2.2.1.3 - Level of Use

The measure of the level of use which is utilized in this analysis is "user days". This is the product of the number of users and the number of occasions of participation per user per year. Data collected in the inventory formed the basis for this calculation.

The various types of facilities were calculated differently. Slips and moorings were assumed to house one boat each, and the average party size is 3.5 persons per boat.[2)] In the Ontario Recreation Survey (1977), recreational boaters in the Hamilton-Wentworth area were found to participate an average of seven times per year.[3)] Therefore, the 987 slips and moorings in Hamilton Harbour used for a summer season of 120 days would produce 24,182 user days. The maximum capacity can be calculated for the Harbour's facilities using a method in the Ontario Recreation Supply Inventory (ORSI). This method would yield a capacity of 207,000 user days for the slips and moorings in the Harbour. To reach this capacity, however, boaters in Hamilton Harbour would have to average 60 days of use per year or 210 user days per year per mooring. The previous estimate, using the Provincial average is a more realistic estimate of actual participation, while the ORSI method presents the potential or maximum capacity of the facilities to provide user days.

Boat ramps are estimated on a different basis than slips. Since no data is kept for actual use of ramps, a method is available from the Ontario Recreation Supply Inventory (ORSI) for estimating use. A ramp is assumed to have a capacity of 25 boats per day.4) The ramps in Hamilton Harbour were reported to be used heavily during the summer months and, therefore, this capacity would likely be reached. It is assumed that this capacity will be attained approximately 50% of the time over the 120 day summer season.5) Since the majority of boats launched at ramps are smaller (under 18 feet), party size is estimated at 2.5 persons.6) Therefore, the four boat ramps on Hamilton Harbour will provide 15,000 user days of boating.

Program participation can also be converted to user days. The inventory indicated that 2,760 persons participated in learn to sail programs. While program length showed some variation, the majority of the programs offered by the Hamilton Harbour Commission were ten sessions in length. This would produce 27,600 user days of boating. The "Y" sailing programs were calculated separately because their program was a different format. The 90 members, averaging 12 sessions per year, would produce 1,080 user days of participation. A total of 28,680 user days would result from programs.

Rowing participation can be estimated based on information from the inventory. According to the Leander Boat Club, approximately 50 active rowers train daily from April to August (152 days) and three days per week from September to October (27 days) for a total of 179 days of participation per person per year. This would yield 8,950 user days of rowing per year.

Based on the data from the facility and program inventory, the quantifiable use of the harbour in 1987 for recreational boating was over 78,000 user days. This total does not include canoeing and kayaking or recreational boaters based outside the harbour who enter and use the harbour occasionally. It is therefore an underestimate of user days of activity. The above estimate was based on an average annual frequency of participation in boating by each participant. The actual participation could be higher although it will not likely reach the maximum capacity of the facilities.

TABLE 2.3

SUMMARY OF USE ESTIMATES RECREATIONAL BOATING

Source of Estimate	Number of User Days per Year
Moorings and Slips	24,182
Dry Sailing	1,225
Ramps	15,000
Programs	28,680
Rowing	8,950
Total	**78,037**

2.2.2 - Fishing

The inventory of warm water fishing activity in Hamilton Harbour explored a number of potential data sources. First, the Ministry of Natural Resources, Fisheries Branch, was contacted to access data from the Ontario Angler Survey and the annual Creel Surveys. Neither of these sources provided adequate data to estimate angling activity in Hamilton Harbour. According to MNR sources, the Ontario Angler Survey asked respondents for their place of residence and body of water fished. Within this data base Hamilton-Burlington residents could be cross-tabulated with Lake Ontario as the water body. No specific data was available for Hamilton Harbour, however.

Data was obtained from the annual creel census by the Ministry of Natural Resources. None of the locations surveyed were within Hamilton Harbour - all were in Lake Ontario. Also, the creel surveys were oriented toward only cold water species such as salmon and trout.

In order to estimate warm water fishing activity in Hamilton Harbour, interviews were held with individuals in Hamilton and Burlington from fishing clubs, fisheries agencies, naturalist/environmental groups, boating clubs and marinas. The result of this survey was a base of anecdotal data on location and degree of fishing activity in the harbour. Interview respondents were asked to relate locations where they had observed fishing activity, the time of the week and season, and the number of persons fishing at that location.

2.2.2.1 - Observed Fishing Activity

A great deal of fishing activity was observed in Hamilton Harbour by those interviewed in the inventory. A summary of these observations is presented in Table 2.4. Locations are shown in Figure 2.2. Boat clubs and marinas surveyed indicated that some members had boats rigged for fishing. These boats, however, are used for salmon fishing in Lake Ontario and not warm water fishing in Hamilton Harbour and therefore these are not considered in this analysis.

Most fishing taking place in the harbour can be characterized as urban recreational fishing. Almost all of the activity observed was shore fishing. Although adults were observed, a large number of those observed fishing in the harbour were youths.

TABLE 2.4

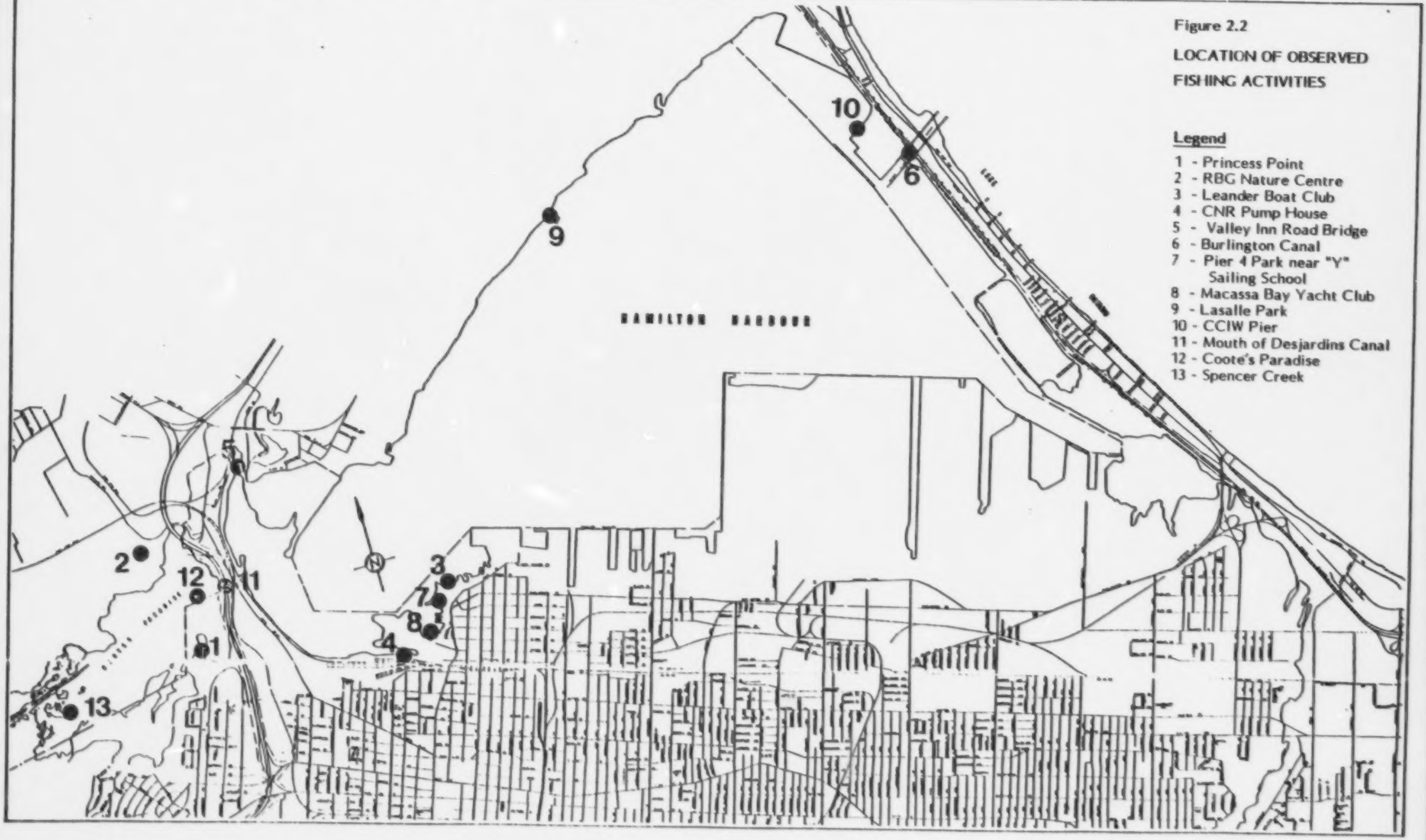
FISHING ACTIVITY OBSERVED IN HAMILTON HARBOUR

	Location	No. of Anglers Observed	Day of Week and Season
1.	Princess Point[6][1]	2 - 3	Summer Weekend
2.	RBG Nature Centre	15	Peak Summer weekend
3.	Leander Boat Club & Dock[6]	10	Summer Weekend
4.	CNR Pumphouse [6]	5	Group Fishes 3-5 times/week
5.	Valley Inn Road Bridge[2][5]	25 - 30	People on bridge on spring weekends
		3 - 5	Summer weekends
6.	Burlington Canal[6]	15 - 20	Spring only
7.	Pier 4 Park near YMCA Sailing School	3 - 4	Summer weekend
8.	Macassa Bay Yacht Club[4]	2 - 3	n/a
9.	Lasalle Park[6]	10 - 30	Typical summer weekend
10.	CCIW Pier[2]	2 - 3	Typical summer weekend
11.	Mouth of Desjardins Canal[2]	2 - 3	n/a
12.	Coote's Paradise[2]	1 boat (2)*	n/a
13.	North Shore & Other Locations[5]	8	Weekend tournament

Sources:

1) Barb McKeen, RBG
2) Keith Rodgers, CCIW
3) Kevin Christenson, City of Hamilton
4) Norm Robinson, MBYC
5) Vic Cairns, CCIW
6) Ron Agnew, Bassmasters

n/a - not available
* - assumed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HAMILTON HARBOUR
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Figure 2.2

LOCATION OF OBSERVED FISHING ACTIVITIES

Legend

1 - Princess Point
2 - RBG Nature Centre
3 - Leander Boat Club
4 - CNR Pump House
5 - Valley Inn Road Bridge
6 - Burlington Canal
7 - Pier 4 Park near "Y" Sailing School
8 - Macassa Bay Yacht Club
9 - Lasalle Park
10 - CCIW Pier
11 - Mouth of Desjardins Canal
12 - Coote's Paradise
13 - Spencer Creek

Several warm water and cold water species were reported caught in the harbour and are listed in Table 2.5. Grindstone Creek at the Valley Inn Road Bridge is reported to have an indigenous trout population and up to 30 people at a time have been observed fishing from the bridge and shoreline.

TABLE 2.5

FISH SPECIES CAUGHT IN HAMILTON HARBOUR*

1. Brown Bullhead
2. Carp
3. White Sucker
4. Pike
5. Largemouth Bass
6. Smallmouth Bass
7. Trout (Brown)
8. Salmon (Chinook & Pink)
9. Sunfish
10. Sheephead
11. Smelt
12. Perch
13. Crappy

* *Species listed are as reported by interview respondents.*

Fish species commonly found in Lake Ontario, such as salmon, rainbow trout, lake trout and sheepheads have been caught in the Burlington Canal. A recent bass tournament in the harbour, attended by eight anglers, yielded 31 largemouth and smallmouth bass. Also caught were a chinook salmon and several pike. The most common species caught throughout the harbour are carp, bullheads, pike, perch, sunfish and bass.

2.2.2.2 - Level of Use

The anecdotal data collected through the interviews are not representative of the population in general and should not be considered a sample based on the level of activity of various days of the week, seasons or times of day. The observations recorded in the previous section were usually the number of people observed at a particular location on "a summer weekend", a "sunny summer day", or a "weekend in the spring". Projecting these general observations to a full year is difficult. The accuracy of such a projection would depend on how representative the individual observations are of the season-long fishing activity. Care should be exercised in interpreting this data. They are presented here for discussion purposes.

The majority of the warm water fish observations were summer weekends. If the summer season is assumed to be June 21 to September 21, there would be 11 summer weekends. An estimate of user days could be made by multiplying the number of summer weekend anglers by the number of summer weekends. To determine the number of summer weekend anglers, the number of observed anglers is multiplied by a turnover rate of 2[6)] and by the number of days in the weekend (2). From the inventory, 67.5 anglers were observed on summer weekends (this is an average of the high and low ranges stated). The resulting level of use is approximately 3,000 user days. To this can be added the spring fishing estimate which is calculated in the same way as the summer weekend estimate. If the spring season is assumed to be May 1 to June 21, there will be 8 spring weekends. With an average of 45 spring weekend anglers, the resulting use level is approximately 1,500 user days. Also reported was one boat (2 anglers) and the bass tournament (8 anglers). Total user days based on this method of estimation from the observed data is approximately 4,500 user days of fishing per year.

2.2.3 - Environmental Interpretation and Outdoor Education

The number and extent of participation in environmental interpretation and outdoor education activities was determined through interviews with staff at the Royal Botanical Gardens, the Board of Education, naturalist clubs and Conservation Authorities in the Hamilton-Burlington area. Interviews probed for the number of programs and activities offered, number of participants, frequency of use and location of activities.

In the context of this report, "environmental interpretation and outdoor education" includes all types of education and appreciation of the natural environment of the Harbour. Interpretive programs, outdoor education, naturalist outings, appreciation of wild life and waterfowl, and water ecology study are all included in this category.

2.2.3.1 - Outdoor activities and Programs

The most important provider of environmental interpretation and outdoor education opportunities in the harbour area is the Royal Botanical Gardens. Outdoor opportunities are provided through the complex of trails which winds through the Coote's Paradise wildlife sanctuary. The sanctuary includes 800 hectares of land and water, and approximately 30 kilometres of trails. Several programs are offered including the following:

- The Junior Naturalist program involves 40-50 youths who participate 1-2 times per month. Two to three guided hikes for youths 15 and over are offered over 15 weeks in the summer.
- Royal Botanical Gardens day camp include four one-week day camps in the summer. Each camp can include 15-25 children. The actual number who are admitted to the program varies from year to year and depends on funding available to hire staff.
- Guided canoe trips are provided on a request basis for church groups, scout leaders, naturalist groups, hiking groups and others. These trips are for ages 5-16 and over. Generally 2-3 trips are organized per year but there have been as many as 10 per year in the past. In 1988, up to 12 trips will be offered as a regular program. Typically, 2 canoes participate per tour.
- Guided hikes for scouts and guides are held each Saturday morning throughout the school year. Groups average about 20 persons.
- A Nature Centre provides interpretive displays of flora and fauna found in the wildlife sanctuary, a beehive demonstration, geology displays, and aquaria and terraria. Although exact records are not kept, staff at the Royal Botanical Gardens estimate that over 50,000 people per year visit the Nature Centre. Approximately 12,000 of these are through school programs and 38,000-40,000 are from the general public.
- Programs offered in conjunction with schools provide opportunities for approximately 10,000 school children per year.
- Public education and interpretive activities for the general public through a guided program involve about 1,500 to 2,000 people per year.

In addition to the organized programs, people are free to use the trails in the nature sanctuary at any time. No data is available on the level of use of these trails but the

Royal Botanical Gardens staff estimate that up to 1,500 could use the trails in the north shore at one time on a summer day. They also estimate that use of the trails may be up to 10 times the level of use of organized programs.

The second largest provider of environmental interpretation and outdoor education programs is the Hamilton Board of Education. The Board has two nature centres with one located near the harbour on the south shore of the Royal Botanical Gardens. In total, 29,000 children are involved in outdoor education programs with approximately 10,000 of these utilizing the harbour area at the Glen Road Nature Centre.

The Hamilton Naturalists Club also provides opportunities for outdoor education through its interpretive walks and outings. The club has over 500 members with about one-third from Hamilton, one-third from Burlington and one-third from Dundas, Ancaster and other areas. Activities organized by the Naturalist's Club include:

- Duck counts which involve 20-25 people. These are held 2 to 3 times per year.
- Bird outings. Last year 20 walks were held with 15-25 persons attending each.
- An environment clean-up day is held annually with about 40-50 persons participating in the harbour area.
- A pond rehabilitation project to eliminate carp from a wetland involved 10-20 people.

2.2.3.2 - Level of Use

The information gathered through interviews on the number of participants and in some cases frequency of use were used to estimate the total number of user days of outdoor education activity.

The Junior Naturalist Program involves an average of 45 youths for approximately two months in the summer. If it is assumed that they participate twice per month, then 180 user days of participation result.

The 4 day camps run for one week (5 days) each, and last year involved approximately 15 children each. In total this would result in 300 user days of activity.

To estimate the level of use of canoe trips it can be assumed that 3 trips were run this year with 2 canoes and 6 persons. In total about 20 user days of canoeing activity are estimated.

Guided hikes take place on weekends in the school year (approximately 40) for groups of about 20 scouts and guides. It can be estimated that 800 user days of guided hikes took place last year.

The Nature Centre provides opportunities for about 38,000 people from the general public and 12,000 school children. Interviews indicated that people generally visit once per year. Therefore, the level of use of the Nature Centre is approximately 50,000 user days.

Board of Education programs provide opportunities for 10,000 children at the Glen Road Nature Centre in the harbour area. As above, it is assumed that these children participate once per year. This yields 10,000 user days of participation.

Use of programs offered by the Hamilton Naturalist's Club were estimated using interview information. Duck counts this year (3 counts) were estimated to involve 25 people for a total of 75 user days. The 20 bird walks, with an average of 20 participants, would provide 1,500 user days of use. Finally, the environmental clean-up provided about 50 user days and the pond rehabilitation project about 30 user days.

Table 2.6 summarizes the estimates of use of the harbour for outdoor education. The total level of use estimated for the harbour area is approximately 63,000 user days. The majority of this is provided in the Nature Sanctuary at Coote's Paradise. This estimate includes only use through organized programs. It does not include casual unstructured use of trails which could not be accurately estimated.

TABLE 2.6
ESTIMATES OF USE OF HAMILTON HARBOUR FOR OUTDOOR EDUCATION

Program	User Days
Junior Naturalists	100
Day Camps	300
Guided Canoe Trips	20
Guided Hikes	800
Nature Centre	50,000
Board of Education Programs	10,000
Duck Counts	75
Birding Walks	1,500
Environmental Clean-Up	50
Pond Rehabilitation Project	20
Total:	62,865

2.2.4 - Shipping And Navigation

Commercial shipping has continued to be a major use of Hamilton Harbour. Bulk materials are transported to the Stelco and Defasco steel mills, and containerized and other cargo is transferred through the port facilities. Anchorage for lake and ocean-going ships is provided with 11,570 metres of warehousing and 88 hectares of storage land is available. Recent development of the East Port Industrial Park along the Hamilton Beach strip will increase the amount of industrial land and wharf space on the harbour by 69 hectares.

Shipping activity is restricted to the period of the year when the Harbour is free of ice. In 1986, this ice free period ran from April 15 to December 21.

In the past ten years, the level of shipping activity in the harbour has fluctuated. Since 1922, the tonnage handled in the port has steadily increased. However, due in part to the economic downturn in 1982, shipping has decreased. Table 2.7 shows the trends in tonnage handled in the harbour. Tonnage has levelled off and is expected to remain relatively stable with modest yearly increases.

TABLE 2.7

TONNAGE IN AND OUT OF HAMILTON HARBOUR

Year	1965	1970	1975	1980	1986
Tonnage Handled (Metric Tonnes)	10,100,000	12,900,000	14,200,000	14,300,000	10,780,862

Source: Hamilton Harbour Commissioners

While tonnage processed in the harbour has varied, the number of vessel arrivals has been relatively stable, as shown in Table 2.8. This reinforces the assertion that the port activity will remain stable in future and that commercial shipping will remain a major use of the Harbour.

A recent study be Sproule-Jones (1987) characterized the shipping in the Port of Hamilton. Sproule-Jones found that Hamilton is primarily an import as opposed to an export port. Exports are generally less than 7% of imports7). Another characteristic of the Port is that the tonnage shipped through the port is mostly steel inputs imported by Stelco and Dofasco. These products are generally greater than 80% of the total port tonnage8). It can be concluded from this analysis that the majority of shipping in the Port consists of imported steel inputs (dry bulk) to the Stelco and Dofasco docks.

TABLE 2.8
SHIPPING TRENDS

Year	Total Tonnage (million metric tonnes)	Overseas Tonnage (million metric tonnes)	Vessel Arrivals (No. of Ships)
1982	8.6	1.17	564
1983	10.2	0.40	565
1984	12.3	0.54	682
1985	10.3	0.57	564
1986	10.8	0.84	626

Source: Hamilton Harbour Commissioners, Annual report, 1986.

2.2.5 - Wastewater Receiving Body

A major use of Hamilton Harbour is as a wastewater receiving body from both point and non-point sources. Effluent from municipal sewage treatment plants and industry flow into the Harbour. As well, non-point sources such as storm sewer runoff and agricultural runoff enter the Harbour. It is an important use and will continue to be in the future.

Sources of wastewater, pollutant loadings and the effects of these loadings on water quality and aquatic life have been well documented in previous studies such as Hamilton Harbour Technical Summary and General Management Options produced by the Ministry of the Environment. Although an important use of the Harbour, wastewater will not be discussed in detail in this study since it has been the major focus of previous studies.

2.2.6 - Industrial Water Supply

Harbour water is used for industrial processes primarily by the two Steel companies. Stelco and Dofasco use approximately 500 million gallons of Harbour water per day. This use has been discussed in previous documents and will not be elaborated upon in this portion of the study.

2.2.7 - Other Recreation Activities

Ice boating is a winter use of the Harbour. This activity takes place primarily in Coote's Paradise. Current levels of use of the Harbour for ice boating are estimated based on interviews with local participants. Iceboaters are active in the area and have held regattas in the past.

The season for iceboating is approximately 12 weeks long, running from the first weekend in January to the third weekend in March with 1 or 2 weekends where snow conditions make use impossible. It is primarily a weekend sport. Interviews indicated that an average weekend would see about 30 iceboaters on any one day, half of the iceboaters are local and half are from outside the Region.

Level of use can be estimated from the interview data. Assuming 10 weeks of snow-free ice and 30 iceboats on each of 2 days on the weekend, and an average of 1.5 iceboaters per boat, there are approximately 900 user days of iceboating per year on Hamilton Harbour.

Another winter sport which takes place on the Harbour is skating. No data is available on current levels of use. Interviews with staff at the Royal Botanical Gardens indicated that individuals sometimes skate in the Coote's Paradise area. No information indicated that a significant amount of skating takes place in the Harbour area.

2.3 Public and Stakeholders' Opinions

Opinions of the stakeholders and the public have been documented in previous reports including the interim report, Hamilton Harbour's Water Quality: the Stakeholder's Proposals (1986). Through the interviews conducted to inventory past and present uses, many of the stakeholder groups were contacted again primarily to gather information. However these interviews also served to confirm and focus the future use options specified in the above stakeholders' report.

The interviews with stakeholder groups and users of the Harbour demonstrated that opinions on what remedial actions were needed in Hamilton Harbour varied among the user groups. However, all stakeholders expressed a commitment to the improvement of Hamilton Harbour for these uses. The proposed future uses of the Harbour as specified in the Stakeholders' report, represents a concensus of these varied views.

This present report adopts the set of future uses for Hamilton Harbour as representative of the views of the Stakeholders. They will provide the basis for the analysis of both present and future uses, and the analysis of costs and benefits of the Remedial Action Plans.

2.4 Future Uses

2.4.1 - Boating

The potential use of Hamilton Harbour for recreational boating was assessed using qualitative data derived from interviews, and estimates of potential participation based on data from the Ontario Recreation Survey (ORS). Interviews were conducted to assess both present and potential future use of the Harbour, and possible effects of improved water quality on use. Data from the ORS was used to estimate the total potential participation in recreational boating by residents of Hamilton and Burlington.

Interviews with representatives of the Hamilton Harbour Commission, boat clubs and marinas were conducted to provide qualitative information on changes in use created by improvements of water quality in the Harbour. The analysis addressed a number of types of recreational boating including sailing (both keelboats and dinghies), powerboating, rowing and canoeing/kayaking.

Several conclusions can be drawn following the results of the interviews. The level of use by power and sailboats will not be affected by water quality so much as by the number of available facilities. Boat club and marina representatives interviewed felt that improved water quality would not have a major effect on the amount of boating use of the Harbour because use is constrained to such a great extent by lack of facilities and access. Although the effect of improved water quality would not be manifested until the access and facility availability is improved considerably, it is still a major issue. All of the boating groups surveyed identified water quality as a major issue and an area where improvements is required. It can be concluded, however, that improvement in water quality would increase the quality of boating experiences in the Harbour and therefore the amount of enjoyment derived from the experience.

Water quality improvement will have varying levels of impact on the different types of boating activity. The levels of use of large powerboats and keelboats will not be affected to a great extent because body contact with the water is not necessary.

Small dinghy sailing is constrained somewhat by poor water quality. Water contact is possible since small sailboats are often capsized. Sailing instruction, which usually involves practice of capsizing and righting procedures, would be constrained as well. One sailing school operator indicated that because of poor water quality in the Harbour, students were not required to participate in capsizing practice in the water. Canoeing and kayaking similarly have potential for water contact and participation is affected as a result, The activity most affected by water quality in the Harbour is boardsailing. Boardsailors are usually immersed in water at some point during the activity. Beginners, in particular, spend a great deal of time in the water. Boardsailing is a very popular and growing sport throughout Ontario. Given the size and sheltered nature of Hamilton Harbour, the level of boardsailing activity is low. Some boardsailing activity was reported by those interviewed; however, a quantitative analysis of boardsailing activity was not possible within the scope of this study.

Since the supply of facilities and access to the Harbour are limited, most of the boating activity identified above takes place in locations other than Hamilton Harbour. With water quality improvement some of this activity could be attracted to the Harbour when the quality and attractiveness of the Harbour equals or exceeds that of alternative opportunities. The amount of boating activity which will actually be diverted to Hamilton Harbour is not clear at this time. A number of members of Hamilton Yacht Club are residents of the Toronto area, although this diverted demand may be the result of over-crowding in Toronto and the sheltered nature of Hamilton Harbour rather than water quality or the relative attractiveness of the harbour.

Future development of recreational facilities on the Harbour will dramatically increase the supply of boating opportunities. The Hamilton Waterfront Master Plan proposes development of facilities which will alleviate the constraint of lack of facilities and access. The plan identifies the potential to expand the number of slips and moorings on the Hamilton waterfront by as many as 1,205. In addition, the Master Plan calls for 32 visitors slips, a dinghy launch area, a non-sail small boat launch area, a wharf, a canoe rental area and boat rentals at the marina. This development will not only provide a large number of additional long-term moorings for recreation boats, but also improve access for day use boats, and allow those who do not own boats to participate using rental boats.

Potential participation in recreational boating by residents of Hamilton and Burlington was estimated by applied the rate of participation found in the Ontario Recreation

Survey (1977) to the present population. Although the study is not current it is the most comprehensive survey of recreational activity undertaken in the Province to date.

The Ontario Recreation Survey (ORS) indicated that 11.2% of the population of Hamilton-Wentworth Region participates in recreational boating (sailing and power boating.9) Therefore, a total of 60,500 recreational boaters are estimated for Hamilton-Wentworth and Burlington.10) Using the ORS method to calculate level of use, it is estimated that Hamilton-Burlington residents participate in 1.7 million user days of boating per year.11)

A final limit to participation to be considered is the size of the Harbour itself and its capacity for boating. Using the ORSI method of calculating capacity, the Harbour will allow approximately 50,000 user days of boating per year. This is based on 2,000 hectares of open water, 3.5 persons per boat and 8 hectares per boat. This figure may not relate directly to the estimate based on numbers of facilities because facilities/boats are not always used to capacity, boats moored in the Harbour do not necessarily use only the Harbour itself and often boating can and does take place at much higher densities than 8 hectares per boat.

2.4.2 - Fishing

The future use of Hamilton Harbour for fishing was assessed using qualitative information from interviews and a surrogate analysis of fishing patterns in a similar urban area. Through the course of the interviews conducted in conjunction with the present use survey, qualitative information was collected on the possible effect of improved water quality on the level of fishing activity and quality of fishing. No surveys have previously been conducted on fishing in Hamilton Harbour and, therefore, patterns of activity for the area are not known. The anecdotal data compiled in Section 2.2.2 of this study were not considered an adequate base for projections of future use. To estimate the potential level of use of the Harbour in the future, patterns of activity of urban anglers in the Metropolitan Toronto area were used as a model. These two estimation methods will combine to give a general picture of the typical effect of water quality on fishing in the Harbour and the potential level of use.

Interviews were conducted with fisheries biologists and representatives of curling clubs, boating clubs and naturalist clubs. The result of these interviews was a qualitative assessment of the potential for fishing in the Harbour.

Through the interviews, a number of common factors were identified which will effect the level the fishing activity and quality of the experience. First, water quality and fish habitat improvements would improve the quantity and quality of fish stock in the Harbour. The amount of fishing activity in the Harbour would increase as the numbers of available fish increased. More popular warm water sport fish such as smallmouth and largemouth bass, pike and whitefish, would create more interest among anglers and, therefore, provide more fishing activity in the Harbour.

A second factor affecting use is public perception of the Harbour. The present public image of Hamilton Harbour is poor. Improvement in water quality and development of a healthy sport fish population, in conjunction with a public information and education program, would improve the public's perception of Hamilton Harbour. With a change in the public image of the Harbour would come an increase in the amount of fishing activity.

A third factor presently limiting the level of use of the Harbour for fishing is access. Any increase in demand for fishing in Hamilton will require improved access for anglers. This will mean more boat launching ramps and public access to the shoreline for shore fishing are needed to satisfy this demand.

While the above qualitative data assisted in identifying the general potential for angling in Hamilton Harbour and the factors affecting use, it did not provide any quantitative assessment of that potential. In order to estimate the potential level of fishing activity, a surrogate analysis was utilized. The surrogate analysis used a study of urban fishing patterns in Metropolitan Toronto12) as a model to estimate fishing activity in Hamilton Harbour. The Toronto study was particularly useful and appropriate as a model because it focussed on "urban fishing". Although no demographic data was available to assess the similarity of Toronto and Hamilton area anglers, the characteristics of the urban fishing populations were assumed to be similar enough for such a comparison. Boat fishing was separated from shore and inland fishing in the data. This differentiation also applies to Hamilton Harbour where boat fishermen were found to fish primarily for salmonids in Lake Ontario and fishing within the Harbour was almost entirely shore fishing.13)

In the Toronto study, 51.7% of the households surveyed had a household member who fished.14) Assuming the same percentage in Hamilton-Wentworth and Burlington, there are potentially 101,177 anglers in the area.15) Of the population who were anglers, 10% fished locally.[16)] If this rate is applied to the Hamilton-Burlington angler population, the potential population fishing in the area can be estimated at 10,118 anglers. From the Toronto data, it was not clear what proportion of the total population were boat fishermen or shore fishermen. However, the portion of the study which surveyed waterfront sites indicated that equal numbers of shore and boat fishermen were surveyed.[17)] It is assumed that recreational fishing in the Hamilton Harbour will be primarily shore fishing and thus 50% of the local anglers will fish within the Harbour. An estimate of the potential number of local anglers fishing in the Harbour is 5,059.

In the same study, a survey of inland fishing sites was implemented. An analysis of the results of that survey produced an estimate that the average angler fished approximately 16 times per year.[18)] This is a very rough estimate but will be used here in the absence of other data. Using this frequency of participation it can be estimated that local anglers would potentially spend 80,944 user days fishing in the Harbour. This potential demand would, of course be constrained by access, facilities and the number and quality of fish available. The extent to which these factors will limit actual fishing activity is not known. Most of the fishing activity identified above takes place outside of the Harbour. With water quality improvement some of this activity could be attracted to the Harbour.

A comprehensive analysis of potential fishing access sites is not possible within the scope of this study. The full extent of future public access to the Harbour shoreline is not sure at this time and will depend on public policy and the amount of development of the Harbour for recreational purposes. Only a qualitative assessment of current development plans is possible.

The Hamilton Waterfront Master Plan proposes a major recreational development in the Harbour area. This proposed development would encompass much of the southwestern part of the Harbour stretching from the Hamilton Harbour Commission Marina through the Desjardins Canal to Princess Point in Coote's Paradise. A designated fishing area is provided on the "Hamilton Island" portion of the site although the plan calls for fishing access along the entire waterfront. If this level of access for shore fishing is provided, access should no longer be a major constraint to shore fishing in the Harbour.

The most limiting factor constraining sport fishing in Hamilton Harbour is the number of desirable sport fish available. At present most of the fish population in the Harbour is Carp. Warm water sport fish species such as pike, large mouth bass and small mouth bass exist in very small numbers. With the planned developments on the Hamilton Waterfront to improve public access, the number of potential anglers would be much greater than the opportunities provided by the biological resources of the Harbour. In other words, the number of opportunities to fish in the Harbour will be limited by the number of fish in the Harbour, and in particular, will be greatly influenced by the number of fish which can be supported by the remedial and mitigative measures to improve fish habitat.

2.4.3 - Environmental Interpretation and Outdoor Education

Future educational use of the Harbour and the effect of water quality on future use was assessed using qualitative data from interviews with the Royal Botanical Gardens, the school board and naturalist groups.

Interviews with representative of the Royal Botanical Gardens (RBG) indicated that the total number of people using programs and trails at Coote's Paradise and the Botanical Gardens will increase slightly as a result of improvements in water quality. The ultimate level of use of RBG's programs is constrained by funding and staffin. The ultimate level of the RBG's interpretive facilities and trails at Coote's Paradise is constrained by the carrying capacity of the area. Several trails have already been closed to manage the amount of use in the area. However, the amount, type and quality of programming would be affected considerably by enhanced water quality and wildlife habitat. More plentiful aquatic vegetation and more numerous and diverse wildlife populations would provide better opportunities for environmental educational programs than are available now. Also, better water quality will allow program participants, particularly children, to have more direct contact with water and the environment. At present, concerns about water quality and the health of children in the programs prevent them from coming in contact with water in the bay.

The increase in numbers and diversity of wildlife resulting from water quality and habitat enhancement would provide more opportunities for naturalist clubs as well. With more wildlife and species such activities as Duck Counts and birding walks could expand. The Hamilton Naturalists Club indicated that the Junior Naturalists program and conservation activities were areas where participation is growing. Conservation projects such as wildlife and fish habitat enhancement could involve these groups and provide increased opportunities for environmental education activities.

There is potential for enhancement of wildlife habitat in numerous locations in the Harbour area. In addition to Coote's Paradise, interviews indicated that there is potential for wildlife habitat in the area near the Canada Centre for Inland Waters and Windemere Basin.

2.4.4 - Shipping and Navigation

Information to assess the future use of the Harbour for commercial shipping and navigation was obtained through interviews with a representative of the Hamilton Harbour Commission. Data on past trends were obtained through published reports provided by the Harbour Commission, previous studies and qualitative information obtained through interviews. As described in the Past and Present Uses section of this report, the amount of shipping, both number of ships entering the port and tonnage, have levelled off in recent years. In the future, the Harbour Commission expects the amount of shipping to remain relatively stable and perhaps increase slightly. This is supported by a recent study by Sproule-Jones (1987) who contend that the type and volume of shipping should not change significantly in the next 15 years.19)

Use of the Harbour for shipping and navigation will not be affected by improvements in water quality and habitat. Although environmental controls to maintain water quality may make more demands on the Harbour Commission, the shipping industry and other industries on the waterfront, this should not affect the amount of shipping using the Harbour. Shipping levels are more likely to be affected by facilities offered in the port, alternative facilities and economic conditions.

2.4.5 - Swimming and Water Sports

Future use of the Harbour for swimming and water sports was assessed through interviews with parks and recreation departments in Hamilton and Burlington, and conservation authorities. The potential number of swimmers in Hamilton and Burlington was estimated using participation rates for swimming from the Canada Fitness Survey.

The focus of this section will be on swimming. Other water sports such as waterskiing and boardsailing are considered in the boating section of Future Uses. Boardsailing was considered together with boating because of the sport's connection with sailing. Waterskiing was not addressed directly because the sport requires the use of powerboats. A separate calculation for potential waterskiers in the Harbour, therefore, would result in double counting.

Interviews were conducted with parks and recreation departments in Hamilton and Burlington to obtain qualitative information on potential future use of the Harbour for swimming. The Hamilton Parks Department operates only one waterfront park, Pier 4 Park. This area is presently not suited for swimming. Pier 4 Park is part of the proposed Hamilton Waterfront development which will include a swimming area. The Burlington Recreation Services Department operates Lasalle Park (leased from the Harbour Commission) which also is not presently suitable for swimming.

Interviews with the Hamilton Region Conservation Authority and the Halton Region Conservation Authority indicate that neither own property on the Harbour and therefore will have no impact on future use of the Harbour for swimming.

Swimming is not a present use of Hamilton Harbour. Because of water quality and health concerns, swimming has been prohibited in the Harbour since the 1930's.20) As a result, no agency provides public beaches on the Harbour.

Most of the Hamilton waterfront is occupied by industry, marine operations and transportation facilities. The once popular "beach strip" is now being developed as a new industrial park and series of wharfs. The result of this long term development of the waterfront is a lack of public access.

While water quality is a constraint to swimming in the Harbour, a major constraint to developing future swimming opportunities will be access. One development which will provide public access to the waterfront and ,more specifically, will provide swimming opportunities is proposed in the Hamilton Waterfront Master Plan. The plan calls for a 5 acre swimming lagoon developed at the "Hamilton Island" landfill site at the southwestern end of the Harbour. Due to the restriction on swimming in the Harbour for many years, public access to the Harbour is now limited. Future use of the Harbour for swimming will depend on the development of swimming areas such as the proposed swimming lagoon.

The potential population of swimmers in Hamilton and Burlington can be estimated using statistics from a study of physical activity patterns in Ontario by the Ministry of

Tourism and Recreation.[21) This study estimated that approximately 11% of the population swims each year. As a result, it can be estimated that there are about 46,561 swimmers in Hamilton and Burlington[22). Of these swimmers, 57% would swim approximately 11 times per year, 25% would swim 24 times per year and 18% would swim 32 times per year.[23) The resulting estimate for swimming activity among Hamilton and Burlington residents is 839,494 user days of swimming.

2.4.6 - Wastewater Receiving Body

Wastewater reception will continue to be a major use of the Harbour in the future. The amount of use is dependent on sources of effluent and has been discussed in previous studies. A possible change in this use would occur if point source effluent were diverted to Lake Ontario rather than being discharged into the Harbour. However, indications are that the Harbour will continue to be the major depository of wastewater.

2.4.7 - Industrial Water Supply

Use of water large volumes of water from the Harbour is required by industrial process, particularly the steel industry. Future use of Harbour water for industry was confirmed by the report Hamilton Harbour's Water Quality: The Stakeholder's Proposals (1986). Although the continued use of Harbour water for industry is expected, the level of use depends to a large degree upon the size and type of the processes operated by industry. The future level of use will depend more on the demands of those industrial processes and not on water quality.

2.4.8 - Other Recreational Activities

Recreational activities such as iceboating and skating will not likely be affected by remedial and mitigative measure to improve water quality in Hamilton Harbour. The level of use in these activities, will, however, be influenced by improvements in public access to the shoreline and other recreational developments on the waterfront such as the development of the Lax Property as outlined in the Hamilton Waterfront Master Plan.

2.5 Requirements for Future Uses

Requirements for future uses were identified using existing water quality guidelines. These guidelines set out standards for acceptable levels of water quality to support both recreational use (swimming) and aquatic life.

Water quality requirements for recreational use are set by the Ministry of the Environment (Provincial Water Quality Objectives) and are listed in Table 2.9. These guidelines pertain to recreational activities where the user is immersed in water. The standards are generally applied to swimming but, as was discussed in the Future Uses section of this report, water sports such as boardsailing and several types of boating activities have varying degrees of risk of water contact, and so these standards may apply to those activities as well. Boardsailing should require the same water quality standards as swimming. Dingy, sailing, canoeing and kayaking should also use similar requirements because the risk of immersion of the user in water. For users of larger boats, where the risk of water contact is small, stringent water quality standards are not as imperative.

TABLE 2.9

WATER QUALITY REQUIREMENTS FOR RECREATIONAL USE

Activity/Use	Measure	Requirement
Swimming (and other activities requiring immersion of the user)	Aesthetics	Devoid of debris, oil, scum, any substance which would produce and objectionable deposit, colour, odour, taste or turbidity
	PH	6.5 - 8.5
	Water clarity	Sufficiently clear to estimate depth and see submerged swimmers. Secchi disk transparency of 1.2 m
	Health risk	< 100 fecal coliforms per 100 ml < 1000 total coliforms per 100 ml

Source: Ministry of the Environment

Environmental interpretation and outdoor education are constrained by water quality as discussed in the Future Uses section. Programs may require some contact with water and therefore the water quality guidelines for swimming should apply.

The Provincial Water Quality Objectives specify guidelines for water quality for aquatic life. Water quality must conform to these standards in order to support a healthy fish population. The water quality requirements to allow use of the Harbour for fishing are listed in Table 2.10. These guidelines would also apply to support a healthy wildlife population.

Requirements other than water quality were compiled by the Study Team and were outlined in Section 1. All recreational uses would require shore line improvement. For boating and swimming, shoreline improvement would serve to improve aethetics and the quality of the recreational use. For fishing, and environmental education, shoreline improvement would enhance fish and wildlife habitats. These improvements would include:

- island construction
- riprap along the shoreline
- bank stabilization
- development of gravel beds
- provision for macrophyte growth
- diking to separate uses (ie pike and duck habitats separated from effluent).
- control of carp populations
- development of environment for pike reproduction through shoreline grooming etc.

2.6 Summary

The Phase 2 research on Harbour uses was completed and summarized in the foregoing report. Past and present uses of the Harbour addressed in the report included:

- recreational boating
- fishing
- environmental interpretation and outdoor education
- shipping and navigation
- wastewater receiving body
- other recreational uses

These uses were inventoried and baseline data was collected.

TABLE 2.10
WATER QUALITY REQUIREMENTS TO PROTECT AQUATIC LIFE

Activity/Use	Measure	Requirement
AQUATIC LIFE	GENERAL CONDITIONS	Free from substances attributable to man-caused point-and non-point source discharges in concentrations that: • settle to form objectionable deposits • flood nuisance as debris, scum, oil or other matter • produce objectionable colour, odour, taste or turbidity • harm humans, plants or animals • produce undesirable aquatic life or result in dominance of nuisance species
	AMMONIA (NH_3-N) Unionized	0.02 mg/l
	CYANIDE	0.005 mg/l
	DISSOLVED OXYGEN	4-8 mg/l
	OIL & GREASE	Should not be present in concentrations that: • are detectable as a visible film, sheen or discolouration • are detectable by odour • cause tainting of edible aquatic organisms • forms deposits on shorelines and sediments that are detectable by sight or odour or are deletrious to aquatic organisms.
	TOTAL PHOSPHOROUS	
	• To avoid nuisance algae	20 ug/l
	• Protection of aesthetics	10 ug/l
	• To prevent excessive plant growth	30 ug/l
	TURBIDITY	SECCHI disk increase of 10%
	ARSENIC (As)	100 ug/l
	BERYLLIUM (Be)	11-1100 ug/l
	CADMIUM (Cd)	0.2 ug/l
	CHROMIUM (Cr)	100 ug/l
	COPPER (Cu)	5 ug/l
	IRON (Fe)	300 ug/l
	LEAD (Pb)	5-25 ug/l

Source: Ministry of the Environment

TABLE 2.10
WATER QUALITY REQUIREMENTS TO PROTECT AQUATIC LIFE

Activity/Use	Measure	Requirement
	MERCURY (Hg)	
	• In water	0.2 ug/l
	• In fish	.05 ug/l
	NICKEL (Ni)	25 ug/l
	SELENIUM (Se)	100 ug/l
	SILVER (Ag)	0.1 ug/l
	ZINC (Zn)	30 ug/l
	TOTAL PCBs	0.001 ug/l
	τ-BHC	0.001 ug/l
	HEPTACHLOR EPOXIDE	0.01 ug/l
	ALDRIN	0.001 ug/l
	ALPHA & HEPTACHLOR	0.001 ug/l
	MIREX	0.005 ug/l
	DDT	0.003 ug/l
	ENDRIN	0.002 ug/l

Source: Ministry of the Environment

Future uses addressed in the report included the above present uses plus swimming and water sports.

A number of gaps in data were encountered which bear noting for future study. In particular, data on the extent of fishing activity in the Harbour was not available from existing sources. The Ministry of Natural Resources, which implements angler and creel surveys in Lake Ontario, has not specifically surveyed Hamilton Harbour. Given the importance placed on the revitalization of Hamilton Harbour and the considerable expenditures expected, surveys both of fish populations and angler activity should be undertaken. This would provide baseline data to monitor the results of the implementation of remedial actions.

Actual use of the Harbour for boating was estimated using standard methods. However, the estimates were often based on surveys which were several years old and provincial averages. A household survey to investigate patterns and levels of use of the Harbour would have allowed for more reliable estimates. Also, for such activities as boardsailing, iceboating and even fishing, no local data was available.

2.7 References

1. It should be noted that the marina is operated by a separate entity although most of the space is used by the club.
2. Tourism and Outdoor Recreation Planning Study Committee, Ontario Recreation Supply Inventory, Users Manual, Toronto, April 1975.
3. Tourism and Outdoor Recreation Planning Study Committee, Ontario Recreation Survey, Geographic Dimensions, Toronto, October 1977.
4. Tourism and Outdoor Recreation Planning Study Committee, Ontario Recreation Supply Inventory, Toronto, April 1975.
5. Tourism and Outdoor Recreation Planning Study Committee, Ontario Recreation Supply Inventory, Toronto, April 1975.
6. Tourism and Outdoor Recreation Planning Study Committee, Ontario Recreation Supply Inventory, Toronto, April 1975.
7. Sproule-Jones, Mark, Commercial Shipping and Hamilton Harbour, Occasional Paper No. 5, McMaster University, April 1987, p. 36.
8. Sproule-Jones, Mark, Commercial Shipping and Hamilton Harbour, Occasional Paper No. 5, McMaster University, April 1987, p. 36.

9. Tokarz, G., **Demand for and Supply of Recreational Boating Opportunities in Southern Ontario**, 1979, p.31.

10. 11.2% x the 1986 population of Hamilton-Wentworth and Burlington.

11. Tokarz, G., **Demand for and Supply of Recreational Boating Opportunities in Southern Ontario**, 1979, p.58.

12. MTRCA, **Urban Fishing: Feasibility Study**, 1986.

13. Based on comments in several interviews.

14. MTRCA, **Urban Fishing: Feasibility Study**, 1986, p.31.

15. 195,700 households in Hamilton and Burlington x 51.7%.

16. MTRCA, **Urban Fishing: Feasibility Study**, 1986, p.31.

17. MTRCA, **Urban Fishing: Feasibility Study**, 1986, p.14.

18. MTRCA, **Urban Fishing: Feasibility Study**, 1986, p.19.

19. Sproule-Jones, Mark, Commercial Shipping and Harbour, Occasional Paper No. 5, McMaster University, April 1987.

20. Gorrie, Peter, **"Cleaning Up Hamilton Harbour"**, Canadian Geographic, 107(3), p.42.

21. Ministry of Tourism and Recreation, Physical Activity Patterns in Ontario III, 1986.

22. Based on 1985 population estimates for Hamilton and Burlington.

23. Fitness and Amateur Sport Canada, Canada Fitness Survey, 1983.

3.0 REMEDIAL AND MITIGATIVE MEASURES

3.1 Introduction

The purpose of this phase is to address the remedial and mitigative measures for Hamilton Harbour. The capital, operating and maintenance costs for each remedial and mitigative measure are summarized in this report.1) The advantages and disadvantages of each remedial and mitigative measure is assessed and summarized in a matrix format according to its effectiveness in controlling pollutants and achieving the desirable water quality for the identified end uses. A cost effectiveness analysis for a particular set of remedial and mitigative measures is then undertaken.

As per the terms of reference, a remedial measure is any activity which will reduce pollution at a specific source. A mitigative measure is any activity which will enhance the use of the harbour, but does not necessarily reduce pollution.

The existing pollution loadings to Hamilton Harbour have been identified and quantified according to their sources:1) a) point sources include municipal sewage treatment plants and industrial discharges; and b) non-point sources such as combined sewer overflow, storm water runoff and Cootes Paradise. The pollutants discharged or released into Hamilton Harbour are: ammonia, phosphorus, suspended solids, bacteria, heavy metals and toxic contaminants. Existing standards such as the M.O.E.'s water quality management guidelines were used to select the types and the degree of treatment for the identified pollutants.

Mitigative measures for Hamilton Harbour include: improvement of water quality; treatment of harbour sediments; shoreline grooming; habitat development, etc. Both remedial and mitigative measures are evaluated in terms of their effectiveness for pollutant reduction and enhancement of harbour end uses respectively.

The cost effectiveness analysis is presented in two forms. The costs of implementation of four alternative sets of remedial and mitigative measures (see section 3.4) are related to the improvement in hypolimnetic dissolve oxygen and to the change in water clarity and the associated change in littoral fish habitat. Then the costs of implementation of another set of mitigating and remedial measures (see section 3.5) are related to the potential yield of Northern Pike and Large Mouth Bass.

3.2 Remedial Measures

Ammonia and phosphorous from both point sources and non-point sources are identified as major pollutants in the waters of Hamilton Harbour.$^{1)}$ These pollutants have been quantified according to source so that types and degrees of treatment could be selected and determined. Other pollutants such as bacteria, suspended solids and heavy metal contaminants are only briefly addressed in this report because of limited data available. The remedial measures considered to treat phosphorus and ammonia include: upgrading aeration tank facilities; installation of sand filters and dual point chemical addition at municipal sewage treatment plants; and modification of biological treatment plant and blast furnace recycle systems of steel industry. These measures are summarized in tabular form in Table 3.1.

3.2.1 - Ammonia

Oxidation of ammonia to nitrate by nitrifying bacteria in a natural water body can cause a high oxygen demand, resulting in dissolved oxygen depletion. The most effective way to control this high oxygen demand is to reduce the ammonia concentration at the source.

A) Point Sources

The point sources for ammonia that enter the waters of Hamilton Harbour are the effluents from municipal sewage treatments plant and the industrial discharges as outlined following and illustrated in Table 3.1:$^{1)}$

i) Hamilton-Wentworth Sewage Treatment Plant

The Hamilton-Wentworth Sewage Treatment Plant (STP) is the largest source of ammonia, with ammonia loading to Hamilton Harbour of 5,500 kg/d. Ammonia can be reduced to 500 kg/d by increasing the sludge age, to promote nitrification in the activated sludge system. This requires an increase in the hydraulic capacity of the aeration tanks and would result in an increase in the mixed liquor suspended solids concentration. The Hamilton-Wentworth STP already has the extra hydraulic capacity needed for improved ammonia removal, but will require the additional aeration capacity needed to accommodate the higher oxygen demand. The capital

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
REMEDIAL APPLICATION MEASURES
TABLE 3.1

REMEDIAL MEASURE	SOURCE							COST		REMEDIAL ACTION TO LOADINGS		REMARKS
	HWSTP	BSTP	STELCO	DOFASCO	CSO	STORM RUNOFF	CREEKS	Capital	Operating & Maint.	Ammonia Reduction	Phosphorus Reduction	
Ammonia												
1.-Increase hydraulic & aeration capacity	***							$3 million	$350,000\yr	5500 to 500 kg\day		- for upgrading aeration capacity only. Existing facilities have spare hydraulic capacity
-Increase hydraulic & aeration capacity		***						$6 million	$100,000\yr	630 to 200 kg\day		- for upgrading plant hydraulic and aeration capacity
2. Recycle system in blast furnace, upgrade equip. (in progress)				***				$9 million		370 to 170 kg\day		
3. Unspecified work in progress			***					$4 million		156 to 150 kg\day		
4. Retention basins(26 no.) 1 in progress($5 mil.)					***			$60 million		200 to 20 kg\day	70 to 5 kg\day	- $5 million for the initial phase(completed in 1987) of the 26 CSO's
Phosphorus												
1. Sand Filters	***							$35 million	$80,000\yr.		220 to 93 kg\day	
Sand Filters		***						$7 million	$30,000\yr.		47 to 20 kg\day	
2.-more stringent controls on construction runoff						***	***				80 to 40 kg\day (reduce by 50%)	Above Phosphorus measures (Retention basins, filters & decreased runoff) expected to produce a harbour water concentration of 34 mg\m3 as compared to a PWQO value of 20 mg\m3
-minimize peak stream flows							***					
-change farming practices						***	***					
3. Dual point chemical injection	***							$1 million	$30,000\yr.		93 to 31 kg\day	Above Phosphorus measures plus dual point chemical injection expected to produce a harbour water concentration of 23 mg\m3
Dual point chemical injection		***						$1 million	$50,000\yr.		20 to 7 kg\day	
4. Discharge directly to Lake Ontario	***							$20 - 26 million				Direct discharge of STP's to Lake Ontario + retention basins & reduced runoff expected to produce water P conc. meeting PWQO
Discharge directly to Lake Ontario		***										
5. Filters at Dundas STP											7.3 to 2.7 kg\day	
Dual point chemical injection at Dundas STP											2.7 to 1.2 kg\day	
Reroute DSTP effluent to Hamilton-Wentworth STP												

Sources of Information: Ontario Ministry of the Environment, August 1985, Hamilton Harbour Technical Summary and General Management Options, Great Lakes Section, Water Resources Branch.

Rodgers G.K., Cairns V., Marsden J., Murphy T., Selby C., Simser L., Vogt J., February 1987, Interim Report of the Writing Team for the Hamilton Harbour Remedial Action Plan, Towards a Comprehensive Remedial Action Plan for Hamilton Harbour.

cost for upgrading the aeration facilities is estimated to be $3 million with an excepted annual operating cost of approximately $350,000.1)

An alternative that could be used to reduce ammonia loadings to Hamilton Harbour would be to divert the sewage treatment effluent discharge directly to Lake Ontario. The associated capital costs are estimated to be between $20-26 million, depending on whether the effluent is discharged 2 or 3 kilometres from the shore. The annual operating costs are estimated at $40,000.1)

ii) *Burlington Sewage Treatment Plant*

The Burlington Sewage Treatment Plant discharges approximately 630 kg/d of ammonia into the harbour. Increasing the sludge age could reduce the ammonia loading to 200 kg/d. This would require an increase in the hydraulic capacity of the aeration tank facilities. The capital cost for upgrading the aeration tank facilities would be $6 million, with annual operating and maintenance costs of approximately $100,000.1)

Diversion of Burlington sewage treatment plant effluent directly to Lake Ontario, in the same manner as for the Hamilton-Wentworth Sewage Treatment Plant, is an alternative means of reducing ammonia loading to Hamilton Harbour. The capital costs associated with such a remedial measure are estimated to be $18 million, with an annual operating cost of $20,000.1)

iii) *Dofasco Inc.*

Dofasco Inc. is identified the third largest point source of ammonia discharged to Hamilton Harbour. The present ammonia loadings from Dofasco Inc. are 370 kg/day. Dofasco Inc. estimates that this loading will be reduced to 170 kg/day by 1988, by diverting the effluent from the biological treatment plant to the city sewer and by the installation of a blast furnace water recycle system. The associated capital cost for these two remedial actions would be $9 million.1)

iv) Stelco Inc.

The present treatment facilities at the Stelco Inc. site discharge an effluent containing 156 kg/d of ammonia to the Harbour.1) Additional remedial measures would only reduce ammonia loadings from 156 kg/d to 150 kg/d. The cost associated with this ammonia loading reduction are estimated to be $4 million. Any other possible remedial works are expected to have a minor effect upon further reduction.

B) Non-Point Sources

Non-point sources of ammonia discharged to Hamilton Harbour include combined sewer overflows (CSO) and storm sewer draingae which discharge to the west end of the harbour.1) The CSO's discharge directly to the harbour and to Red Hill Creek and Chedoke Creek.

i) Combined Sewer Overflows (CSO)

Parts of the City of Hamilton are served by a combined sanitary and storm sewer system. During a heavy rainfall, this combined sewer system will overflow discharging untreated sewage directly to the Harbour. The sewer overflows contribute BOD, ammonia, bacteria, phosphorus and suspended solids to the harbour waters. Some twenty-six overflow points of discharge to the harbour have been identified but most of the discharge occurs at 12 overflow points. These points mainly service the Central Business District (CBD), the industrial, and the East Mountain. The former two points discharge directly to the Harbour while the East Mountain discharges to Red Hill Creek, primarily at Greenhill but also at Albion Falls. Installation of retention basins to store combined sewer overflows at the 12 main points would cost $60 million in total. After a storm event the sewage collected in these retention basins would then flow by gravity or be pumped to the sewage treatment plant for treatment. Ammonia loadings are expected to be reduced from 200 to 20 kg/day if this remedial action is implemented.1)

There is one additional treatment technique available to control CSO discharges. A computer system using rainfall data could be used to optimize the capacity of the present sewer system and minimize combined sewer overflows. This work has previously been researched at McMaster

University, but has ceased with a change in personnel. McMaster and others have developed ongoing research programs into these issues (B. Snodgrass personal communication).

ii) *Other Diffuse Sources*

Other diffuse sources include stormwater runoff from separated sewers, streams (see Table 1.3; including Red Hill Creek, Grindstone Creek, Rambo Hager Diversion, and Aldershot Drain) and Cootes Paradise.1) Many of the separated sewers discharge into these creeks or into Cootes Paradise and hence, are not included in the loading estimates for separated sewers. CSO discharges to Red Hill Creek have been separated out from stream loading estimates. Agricultural effects on the streams are considered to be combined with urban effects in the loading estimates.

There are no remedial or mitigating measures of significance which have been detailed in the literature. Furthermore, these sources are a small component of total ammonia discharged to the Harbour. Accordingly, these other diffuse sources are considered to be a result of urbanization and not directly addressable with the remedial and mitigating measures considered in this section.

C) Effectiveness of Remedial Measures for Ammonia Reduction

Ammonia loadings before and after implementation of alternative remedial measures are summarized in Table 3.2.

TABLE 3.2

AMMONIA LOADINGS TO HAMILTON HARBOUR

Source	Loadings in 1985* (kg/day as NH_3-N)	Loadings after* Remedial Measures (kg/day as NH_3-N)
Hamilton-Wentworth STP	5500	500
Burlington STP	630	200
Dofasco	370	170
Stelco	156	150
Hamilton CSO	200	20
Total	6856	1040
Reduction	-	85%

STP = Sewage Treatment Plant
CSO = Combined Sewer Overflows
(* Refer to Table 3.1 following page 3-2)

If all remedial improvements were implemented, the total ammonia loadings to the harbour would be reduced by 85% from 1985 levels and would result in ammonia concentrations in the harbour of less than 0.5 mg/L (M.O.E. 1985). This substantial reduction in ammonia levels would allow high oxygen levels, which would in turn enhance harbour water quality. If ammonia levels in the harbour are maintained below 0.5 mg/L, the toxic effects of ammonia on aquatic life will be mitigated. But as noted below (Sections 3.4 to 3.6), oxygen levels are expected to remain low even with this degree of denitrification, due to the high oxygen demand created by plankton and sediments. Whether ammonia levels of 0.5 mg/L are consistently met depends on the exchange deficiencies. An assessment of the toxicity of ammonia is presented at the end of Chapter 3. The implementation requirements of the proposal remedial action plans for ammonia and their advantages and disadvantages are summarized in Tables 3.3 and 3.4.

3.2.2 - Phosphorus

Phosphorus is a limiting nutrient for algal growth. Light and hydrodynamic factors limit algal growth (Harris et al 1979)[9)] often exceeding the role of phosphorus in controlled algae dynamics. The present level of discharge of phosphorus from point

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
IMPLEMENTATION REQUIREMENTS FOR EACH REMEDIAL MEASURE
TABLE 3.3

REMEDIAL MEASURE	SOURCE								MINIMUM TIME REQUIREMENT FOR COMPLETION	COORDINATION WITH OTHER ACTIVITIES	WEATHER REQUIREMENTS	LAND REQUIREMENTS	IMPACT ON OTHER ACTIVITIES
	HWSTP	BSTP	DSTP	STELCO	DOFASCO	CSO	STORM RUNOFF	CREEKS					
Ammonia Reduction													
1a-Increase hydraulic &\or aeration capacities	*****								1a.- 2.5 years	Remedial measures concurrent with mitigative measure of harbour water		1a. aeration tanks	
1b-Increase hydraulic &\or aeration capacities		****							1b.- 3 years			1b. aeration tanks	
2. Recycle water in blast furnace and divert treatment plant effluent					*******				2. - 2.5 years				
3. Unspecified water pollution control work				******					3. - 0.5 years				
4. Retention basins(26 no.) for combined sewer overflows						***			4. - 5 years			4. underground retention tanks	
Phosphorus Reduction													
1. Sand Filters	*****	****	****									1. sand filter structures	
2. Dual point chemical injection	*****	****	****							2. after sand filter installation			
3. Discharge directly to Lake Ontario	*****	****								3. when other control measures fail to meet the water qual. for the end uses			
4. Retention devices to minimize peak stream flows; Structures to protect stream banks; Change farming practices for soil erosion control							******	*******				4. Retention ponds	
5. Diversion of Dundas Sewage Treatment Plant (DSTP) sewage			****										5. Increase pollutant loadings to HWSTP

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
ADVANTAGES AND DISADVANTAGES OF EACH REMEDIAL MEASURE FOR HAMILTON HARBOUR FOR THE SELECTED END USE
TABLE 3.4

REMEDIAL MEASURE	SOURCE HWSTP	 BSTP	 DSTP	 STELCO	 DOFASCO	 CSO	 STORM RUNOFF	 CREEKS	SPECIFIC\OTHER ADVANTAGES	OVERALL ADVANTAGES	DISADVANTAGES
Ammonia Reduction											
1a-Increase hydraulic &\or aeration capacities	***								1a-Reduce BOD loadings, low capital cost with ammonia removal using existing spare tank space	-Reduce ammonia concentration in the effluent water.	
1b-Increase hydraulic &\or aeration capacities		***							1b-Reduce BOD loading	-Reduce ammonia toxicity to aquatic life	1b-High capital cost
2. Recycle water in blast furnace and divert treatment plant effluent					***				2-Reduce water usage	-Reduction of ammonia loading to the harbour	2-High capital and operating cost
3. Unspecified water pollution control work				***						-Reduction of oxygen demand in harbour water	3-very high capital cost for little ammonia reduction
4. Retention basins(26 no.) for combined sewer overflows						***			4-Eliminate sewage overflows -Reduce ammonia, phosphorus, bacterial discharges and BOD to the harbour	-Eliminate possible anoxic condition in water column due to high oxygen demand	
Phosphorus Reduction											
1. Sand Filters	*****	****	****						1. Reduce bacterial discharge and suspended solids loading to the harbour.	-Reduce algal growth -Improve water clarity	1. Very high capital cost
2. Dual point chemical injection	*****	****	****						2. Further reduce phosphorus loading to the harbour	-Enhance light penetration for rooted aquatic plants	
3. Discharge directly to Lake Ontario	*****	****							3. Reduce phosphorus, BOD and suspended solids to harbour	-Eliminate possible anoxic conditions (and consequential fish death) in water column due to high oxygen demand	3.-cause pollution to Lake Ontario -Endanger drinking water quality
4. Retention devices to minimize peak stream flows; Structures to protect stream banks; Change farming practices for soil erosion control							******	*******	4. Reduce phosphorus and suspended solids loadings to harbour, reduce water turbidity	-Reduce phosphorus loading to the harbour	
5. Diversion of Dundas Sewage Treatment Plant (DSTP) sewage			****						5. Reduce organic ammonia and phosphorus loadings to Cootes Paradise		5. Increase HWSTP loadings

Note: Dundas Sewage Treatment Plant measures for Cootes Paradise which in turn affects Hamilton Harbour water quality.

and non-point sources to Hamilton Harbour permits excessive algal growth, which in turn reduces light penetration essential for the rooted aquatic plants. Severe algal growth in the hypolimnion in the summer can also deplete dissolved oxygen to a critical level, detrimental to aquatic life.

A) Point Sources

Point sources for phosphorus are the municipal sewage treatment plants1) as detailed below and tabulated earlier in Table 3.1.

i) Hamilton-Wentworth Sewage Treatment Plant

The Hamilton-Wentworth Sewage Treatment Plant contributes phosphorus loading of 220 kg/d to the harbour. The phosphorus loadings can be reduced to 93 kg/d by tertiary treatment consisting of sand filtration that will remove phosphorus associated with suspended solids in the plant effluent. As an additional positive feature this filtration process will reduce the total suspended solids and other metals being discharged to the harbour. The capital cost for the sand filtration system would be about $35 million, with annual operating and maintenance costs of approximately $80,000.1)

Dual point chemical addition in conjunction with filtration could further reduce the phosphorus loading from 93 kg/d to 31 kg/d, at a cost of $1 million and annual operating and maintenance costs of $30,000. When both filtration and dual point chemical addition are used, total phosphorous can be reduced by 86%.1)

An alternative remedial measure to reduce the phosphorus loading from the Hamilton-Wentworth Sewage Treatment Plant would be to divert the plant effluent discharge directly to Lake Ontario. The costs associated with this alternative are included in the cost of remedial measures for ammonia reduction. The impact of the diversion of this sewage effluent to Lake Ontario is not available and is not addressed in this report.

ii) Burlington Sewage Treatement Plant

Burlington Sewage Treatment Plant presently discharges 47 kg/d of phosphorus to Hamilton Harbour. To reduce the phosphorus loading to

20 kg/d, a sand filtration system could be used which in turn would reduce the suspended solids content of the effluent. This method would cost $7 million, and have annual operating and maintenance costs of $30,000.1)

An additional reduction of phosphorus loadings to 7 kg/d can be achieved by employing dual point chemical injection in conjunction with filtration. The capital cost for the dual point chemical injection system would be $1 million. The total phosphorus reduction resulting from the filtration and dual point chemical injection systems would be 85%.1)

Again, it is possible to divert the Burlington sewage treatment plant effluent directly to Lake Ontario to reduce phosphorus loading to Hamilton Harbour. The costs associated with this alternative are included in the cost of remedial measures for ammonia reduction. The impact for the diversion of this sewage effluent to Lake Ontario is not available and is not addressed in this report.

B) Non-Point Sources

Non-point sources of phosphorus include combined sewer overflows, surface runoff, streams and Cootes Paradise1) as described below and illustrated in Table 3.1.

i) Combined Sewer Overflows

During a heavy rainfall, the combined sewers will overflow, discharging untreated sewage containing phosphorus directly to the harbour. As noted above the installation of retention basins at the twelve overflow points would store these overflows during storm events then direct them to the treatment plant for treatment later. This action could reduce the phosphorus loadings from the current levels of 78 kg/d to 5 kg/d. The costs associated with the retention facilities are included in the remedial measure for ammonia.

ii) Runoff/Streams

Surface runoff and streams transport phosphorus and other pollutants such as suspended solids and possibly toxic chemicals such as PCB's, organic chlorine particles, PAH's, chlorinated benzene and heavy metals (4). Remedial measures to control phosphorus and other contaminant loadings include: protection of stream banks to reduce sediment erosion, changing farm practices to reduce erosion (such as furrowing, crop rotation, filling and establishment of buffer strips to plantings); taking more care on construction sites to control erosion and retention ponds to reduce peak stream flows. Based upon an analysis of farming practise given in the the Appendix E, it is assumed that control of surface runoff/streams would help reduce the phosphorus loading by 50% (from 80 kg/day to 40 kg/day) for a total annual cost of $1.5 million. This is based upon a net farm impact of switching conventional row crop tillage to no tillage of $25 per acre. Further analysis of these estimates of control and costs are presented in the sensitivity analysis.

iii) Cootes Paradise

A majority of remedial measures described earlier will contribute to the clean-up of Cootes Paradise. These measures would include the control of creek runoff, provision of combined sewer overflow retention basins, and point source control of effluent discharges from the Dundas Sewage Treatment Plant. However, the impact of the measures on controlling discharges from Cootes Paradise is not known due to sediment release of phosphorus. In addition a variety of mitigative measures considered later in this report could enhance Cootes Paradise including dredging and formation of cells for fish/wildlife habitat.

Reduction of phosphorus loading to Cootes Paradise could be accomplished by installing sand filters at the Dundas Sewage Treatment Plant, which would effectively reduce loadings from 7.3 to 2.7 kg/day.

Further phosphorus reductions can be achieved at the Dundas Sewage Treatment Plant, from 2.7 to 1.2 kg/day, by dual point chemical injection prior to the filtration process. The total phosphorus loading reduction by the two treatment processes would be 84%.

An alternative remedial measure would be to re-route sewage from the City of Dundas to the Hamilton-Wentworth Sewage Treatment Plant.

The costs associated with each remedial measure at the Dundas plant are not provided in the available literature and where necessary, assumptions of their cost are made as detailed in Section 3.4.4.

C) Effectiveness of Remedial Measures for Phosphorus Reduction

The effectiveness of the remedial measures considered for use in Cootes Paradise influences both Hamilton Harbour and Cootes Paradise. Therefore both receptors are addressed separately as two entities even though there is some transfer of phosphorus loadings between the two due to hydrodynamic exchange.

i) *Hamilton Harbour*

The total phosphorus loadings from both point and non-point sources before and after implementation of the various remedial measures are summarized in Table 3.5

TABLE 3.5

PHOSPHORUS LOADINGS TO HAMILTON HARBOUR*

Source	Loadings in 1985 (Kg/Day as P)	Loadings after Sand Filtration (Kg/day as P)	Loadings after Dual point Chemical Injection (Kg/day as P)
Hamilton-Wentworth STP	220	93	31
Burlington STP	47	20	7
Hamilton CSO	78	5	5
Runoffs/Streams	80	40	40
Total	**430**	**163**	**88**
Reduction	--	**62%**	**80%**

(* Reference: Table 3.1)

Sand filtration used only at municipal point sources and reduction of phosphorus loadings from non-point sources by 50% with the installation of retention devices and/or structures to protect stream banks, and by changing farm practices should reduce the total phosphorus loadings to the harbour by 62%. Based upon M.O.E. (1985) assessments this should reduce the average phosphorus concentration in the Harbour to about 34 mg/cu.m, a concentration, which, is still above the Provincial Water Quality guideline of 20 mg/cu.m (M.O.E., 1985). This proposed action does not take into account any future increased sewage flow which will contribute to phosphorus loading. Based upon M.O.E. (1985) relationships, this reduction of phosphorus levels in the Harbour by the remedial measures considered, will only reduce the annual algal growth by 15 to 35%, and may not result in any noticeable improvement in water quality.

Phosphorus concentrations in sewage treatment plant effluents can be reduced to 0.1 mg/L by employing dual point chemical addition in conjunction with filtration. A phosphorus concentration in the sewage treatment plant effluents of 0.1 mg/L coupled with a 50% reduction from soil erosion and 95% reduction of combined sewer overflows should reduce phosphorus loadings to the Harbour to 89 kg/day; using M.O.E. (1985) relationships, this should give an average phosphorus concentration in the Harbour of about 23 mg/cu.m. The clarity of Harbour water would be expected to improve with Secchi disc depth readings of 1.5 to 2.0 metres and the hypolimnetic oxygen demand from algae would be reduced by 40 to 60%.

An additional remedial action would be to divert the sand filtered treated sewage treatment plant effluents directly to Lake Ontario, with the reduction of combined sewer overflows and a 50% loading reduction from runoff/streams. This combined action would reduce phosphorus input to the harbour to about 50 kg/day. The phosphorus concentration in the Harbour of about 19 mg/cu.m using M.O.E. (1985) relationships would meet the Provincial Water Quality guidelines. Under these conditions M.O.E. (1985) relationships suggest that, water clarity would be greatly improved, with Secchi disc depth reading of 2.0 to 2.5 metres, and the about a 70% reduction in oxygen demand from algal growth. However this alternative, the discharge of sewage treatment plant effluents directly to Lake Ontario, would require study to assess its impact on the water quality in the Lake.

Various reductions in total phosphorus and improvements in water clarity have been suggested above are based upon literature estimates (e.g., M.O.E., 1985). Actual imporvements are computed in Sections 3.4 - 3.5 for a series of remedial and mitigating measures; these calculations based upon a eutrophication (algal-nutrient dynamics) model may differ from the above assessments. Where differences occur, they result from non-linearities considered in the model and not considered in the literature assignments.

ii) Cootes Paradise

Phosphorus loading from the Dundas Sewage Treatment Plant to Cootes Paradise during the critical algal growing season is 7.3 kg/day (MOE, 1985). With the installation of the sand filters, the phosphorus loading would be expected to be reduced to 2.7 kg/day, achieving a 63% phosphorus loading reduction.

The available phosphorus loading from the run-off/streams to Cootes Paradise during the critical algal growing season is estimated to be about 3.4 kg/day.1) Further studies to identify the sources of this phosphorus are needed before remedial measures can be defined. Contribution of phosphorus from the run-off/streams could be reduced by 50% to 1.7 kg/day, by implementing remedial measures for non-point sources.

Phosphorus loadings from Hamilton Harbour are estimated to be about 2 kg/day (M.O.E., 1985). Cootes Paradise would be expected to receive a phosphorus loading of about 0.7 kg/day from Hamilton Harbour if all remedial measures previously identified are implemented. The implementation of these measures would result in a 50% Phosphorus loading reduction.1)

Phosphorus loadings from the Hamilton combined sewer overflows contributing to Cootes Paradise during the critical algal growing season are estimated to be 1.6 kg/day. Installing retention facilities to retain the combined sewer overflows could reduce the phosphorus loadings to less than 0.1 kg/day or a 94% reduction from the original.

The phosphorus loading to Cootes Paradise during the critical algal growing season could be reduced from 14.3 kg/day to about 5 to 6 kg/day if remedial measures were implemented. The phosphorus concentration in Cootes Paradise could be expected to decrease to about 58 mg/cu.m, which is still well above Provinical Water Quality guidelines. The turbidity caused by the expected decrease of algal growth would be reduced by about 40%. However, since much of the turbidity is caused by wind induced erosion of bottom sediments, the overall improvement in water clarity will be much less.

The addition of dual point chemical injection, in conjunction with filtration at the Dundas Sewage Treatment Plant would reduce phosphorus loading further to about 1.2 kg/day. The resultant phosphorus concentration in Cootes Paradise would be about 38 mg/cu.m (M.O.E., 1985). The turbidity caused by the expected decrease in algae would be by about 50% less than present levels.

Diversion of sewage from Dundas to the Hamilton sanitary sewers would reduce the total phosphorus loading to Cootes Paradise to about 2.5 kg/day during the critical algae growing season. The phosphorus concentration in Cootes Paradise would then be about 28 mg/cu.m, with turbidity reduced by about 60%.1)

Remedial measures to control soil erosion include: the use of settling basins for construction site runoff; the use of storm retention basins for peak storm flow reduction, the installation of rip rap on creek beds and banks susceptible to erosion, and modifying farm practices to minimize soil loss. These remedial measures would reduce suspended solids loading to and turbidity of Cootes Paradise.

The implementation requirements, and the advantages and disadvantage of all these remedial measures are summarized in Table 3.3 and 3.4.

3.3 Mitigative Measures

Remedial measures that are implemented may take a few years to meet the water quality criteria goal for the desired end use. Mitigative measures that could enhance the use of the harbour are described following and include: oxygenation and chemical treatment of harbour waters; chemical treatment, physical sealing and dredging of harbour bottom sediments; and dyking, shoreline grooming, habitat development and

Carp control in Cootes Paradise. The mitigative measures[1)] are summarized in tabular form in Table 3.6. The effectiveness of each mitigative measure is also discussed in this section.

3.3.1 - Treatment of Harbour Waters

a) *Oxygenation of Harbour Water and its Effectiveness*

Oxygen addition to harbour waters would provide a desirable level of dissolved oxygen for aquatic life, enhance biodegradation of organic pollutants in the water column, and reduce the toxicity of the heavy metals re-introduced from the sediments. Oxygenation of harbour water can be achieved by destratification or hypolimnetic aeration.

A destratifying action causes full vertical circulation of the water which will destroy thermal startification but enhance the exchange of oxygen at the water surface. Other variations of destratification involve injecting air and water down through one tube of a twin shaft system anchored into the lake bottom. Oxygen dissolution is enhanced under hydrostatic pressure at the bottom of the shaft and the oxygenated water passes back to the lake through other tube by the lifting action of the undissolved portion of the air. This destratification process would cause warming of the hypolimnetic water which has an undesirable effect on fish habitats, particularly in the summer. Cost estimates for destratification by air injection were made in the early 1970's for the Hamilton Harbour experiment but have not been updated.

Hypolimnetic aeration is typically achieved by air bubbling. Using this method, oxygen is introduced gently without destratifying the water column, thereby preventing the mixing of bottom water with the warm surface water. Hypolimnetic aeration enables the bottom water to remain at its normal temperature resulting in a smaller oxygen demand from bottom sediments and maintaining fish habitat. It is estimated Hamilton Harbour requires 40 tonnes of oxygen per day over a 128 day period from mid-summer to mid-fall, during periods of low dissolved oxygen. The requirement of 40 tonnes of oxygen per day required is based on the assumption that the remedial actions described earlier to reduce nutrient loadings from sewage treatment plants are not implemented. The capital cost for this option are estimated to range from $4 to $40 million,

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
MITIGATIVE APPLICATION MEASURES
TABLE 3.6

MITIGATIVE MEASURE DIRECT HARBOUR TREATMENTS	SOURCE							COST		REMARKS
	HWSTP	BSTP	STELCO	DOFASCO	CSO	STORM RUNOFF	CREEKS	Capital	Operating & Maintenance	
1. Oxidation of Water Column -destratification										
-hypolimnetic aeration								$4-40m $2-20m $1-10m	$205,000 (No changes to STP's) $103,000 (Nitrification enhanced) $ 52,000 (Dual point & nitrification)	Hypolimnetic aeration assumptions; 128 days operation, no changes to STP's and 40 tonnes of oxygen injected per day
-oxygen injection								$170,000 $ 85,000 $ 85,000	$360,000 (No changes to STP's) $190,000 (Nitrification enhanced) $100,000 (Dual point & nitrification)	
2. Iron Addition	--	--	----	-----	-	----	-----	---------	----------	----------
3. Lime Application	--	--	----	-----	-	----	-----	--------- 0	---------- $100,000\yr	---------- Lime application assumes two treatments of 400 tonnes each
4. Nitrification - oxidize ammonia to nitrate at STP plants by increasing mean residence time of sewage sludge	***									
- ditto		***								
5. Treatment of harbour bottom sediments - deep water disposal - capping in place										
- combined disposal facilities (CDF's)	----	--	----	-----	-	----	-----	-----------	$4\yd3	
- disposal\storage in quarry\strip mine	----	--	----	-----	-	----	-----	-----------	$12.50\yd3\200 miles of transportation	
- landfills	----	--	----	-----	-	----	-----	-----------	$3\yd3\disposal, $0.45\yd3\mile of transportation	
- solidification in place or after removal										
- upland fill	----	--	----	-----	-	----	-----	-----------	$0.50\yd3\mile for pumping, $185,000\mile for piping	
6. Mitigative Measures to Cootes Paradise incl. - diking\cell separation	----	--	----	-----	-	----	-----	$500k-$1m		
- carp control - environment for pike reproduction ie. shoreline grooming,etc.										
7. Habitat Enhancement - islands - rip rap along shore - bank stabilization - gravel beds - macrophyte growth										
8. Define ship lanes away from shallow areas to reduce disruption of bottom sediments										

Sources: -Rodgers G.K., Cairns V., Marsden J., Murphy T., Selby C., Simser L., Vogt J., February 1987, Interim Report of the Writing Team for the Hamilton Harbour Remedial Action Plan, Towards a Comprehensive Remedial Action Plan for Hamilton Harbour.
-Cairns V., October 1986, Remedial Actions to Restore the Hamilton Harbour Fishery - Draft, Great Lakes Laboratory for Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, Burlington, Ontario
-Remedial Options Work Group, August 25, 1978, Remedial Options for Contaminated Sediments in the Great Lakes Basin, Report of the Remedial Options Work Group to the Sediment Subcommittee.

with an annual operating costs of \$205,000.[1)] This oxygenation rate of 40 tonnes per day would ensure that the sediment oxygen demand is also satisfied.

Hypolimnetic aeration by direct oxygen injection using diffusers has been estimated to be the least expensive and most efficient process for oxygenating the hypolimnion[1)]. Sediment resuspension and water column destratification were not observed. Diffusers do not interfere with navigation. Capital and operating costs for hypolimnetic oxygen injection together with different options of additional treatments for sewage treatment plant effluent are given in Table 3.6.

Implementation requirements, advantages and disadvantages of this mitigative measure is illustrated in Table 3.7 and 3.8a.

b) *Lime Application and its Effectiveness*

Lime addition to harbour waters would bring about phosphorus, heavy metals, algal and suspended solids precipitation. The precipitation process would partially restore the clarity of the water, thus enhance light penetration for rooted aquatic plants, and possibly increase algal growth. Lime addition has a highly negative impact if the pH is raised too much.

Sealing the sediments with lime would result in precipitation of toxic metals as well as prevent toxic metals from re-entering the water column. Periodic treatment of the harbour water would be required on a continuing basis to minimize the return of contaminants from the sediments until the sediments are completely buried with fresh clean sediment. The use of this measure might be an inexpensive alternative to dredging and disposal of contaminated sediments. Lime treatment requires capital costs only for the application boats. The operating costs would be approximately \$100,000/yr.

The implementation requirements and advantages and disadvantages of lime addition are shown in Tables 3.7 and 3.8a respectively.

c) *Iron Treatment of Harbour Waters and its Effectiveness*

Addition of ferrous or ferric compounds to the harbour waters would bring about precipitation of phosphorus and heavy metals (Table 3.8a). Oxygen mediated

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
IMPLEMENTATION REQUIREMENTS FOR MITIGATIVE MEASURE
TABLE 3.7

MITIGATIVE MEASURE	MINIMUM TIME REQUIREMENT FOR COMPLETION	COORDINATION WITH OTHER ACTIVITIES	WEATHER REQUIREMENTS	LAND REQUIREMENTS	IMPACT ON OTHER ACTIVITIES
1. Oxygenation of Harbour Water by a-destratification b-hypolimnetic aeration c-oxygen injection	1a,b,c Depends on dissolved oxygen levels and other water quality levels in the harbour	- all mitigative measures concurrent with remedial measures	- mid summer to mid fall	1b. Building for compressors	1b. restriction to harbour navigation
2. Iron Addition to harbour water			- summer		
3. Lime Application to harbour water	2.-Depends on water clarity, metals and phosphorus concentrations in harbour water	- with lime treatment of sediment			
4. Dredging and Disposal of harbour sediments			- summer only	4.-landfill required if sediment disposal option chosen	4.-cannot be concurrently carried out with oxygenation of harbour water due to further resuspension of sediments in harbour water
5. Physical Sealing of Sediment with Clay			- summer only		5.-cannot be carried out concurrently with oxygenation of harbour water due to further resuspension of clay
6. Lime Treatment of Sediments	6. Depend on water column treatments	6. With lime application of harbour water	- summer only		
7. Nitrate Injection to Sediments	7. Depends on sediment oxygen demand		- summer only		
8. Define Shipping Lanes away from shallow areas to reduce disruption of bottom sediments			- summer only		- increase phosphorus level in the hypolimnion

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR

ADVANTAGES AND DISADVANTAGES OF EACH MITIGATIVE MEASURE FOR HAMILTON HARBOUR FOR THE SELECTED END USE - HARBOUR WATER TREATMENTS

TABLE 3.8a

MITIGATIVE MEASURE	SPECIFIC\OTHER ADVANTAGES	OVERALL ADVANTAGES	DISADVANTAGES
HARBOUR WATER TREATMENTS			
1. Oxygenation of Water Column by a-destratification b-hypolimnetic aeration c-oxygen injection	1b.-Eliminate destratification -Enable hypolimnetic water to remain cool for fishery habitat and not enhance algal growth in hypolimnion and sediment oxygen demand 1c.-Eliminate destratification -Enable hypolimnion to remain cool for fishery habitat, no enhancement of algal growth in hypolimnion and high sediment oxygen demand -very low capital cost and more economical to operate -eliminates barrier to restrict navigation	- increase dissolved oxygen level in water column - improve biodegradation of organic pollutants - enhance oxygen mediated precipitation of metals - eliminate anoxic condition caused by ammonia oxidation and algal growth - improve harbour water quality	1a.-Warming of hypolimnetic water undesireable for fishery habitat -enhanced algal growth in hypolimnion 1b.-Barrier to restrict navigation in the harbour -noise from high capacity compressors -expensive capital cost -limint to summer operation
2. Iron Addition to Harbour Water	2. -local availability of iron makes this cost effective for phosphorus reduction	- reduce phosphorus level in Hamilton harbour by precipitation - reduce algal growth - improve water clarity - enhance light penetration - improve water quality - enhance oxygen mediated precipitation of metals - prevent phosphorus release from sediments	
3. Lime Addition to Harbour Water	3. -low capital cost -very economical and effective for harbour water treatment no adverse effects on zooplankton or fish	- precipitate phosphorus and suspended solids in harbour water - improve water clarity - enhance light penetration for rooted aquatic plants - precipitate metals - use as barrier to seal the harbour bottom sediments - improve water quality	3.-enhance possible algal growth by allowing for greater light penetration

precipitation of metals could be more effective if more reactive iron compounds were added to the Harbour waters. The apparent low rate of phosphorus release from the Harbour bottom sediments is probably a reflection of the high iron concentration in the sediments which resulted from the large historical iron loadings to the harbour.

The implementation requirements and advantages and disadvantages of iron treatment are shown in Tables 3.7 and 3.8a respectively.

d) *Nitrate Treatment and its Effectiveness*

Increasing the nitrate concentration in harbour waters would oxidize the sediments. This could suppress the sediment oxygen demand to some degree by reducing the flux of reduced cations from the anaerobic sediments although this effect is small (Walker, 1986)10). It may increase the phosphorus flux due to the increase in the combined thickness of the aerobic/anoxic zone; it may decrease the phosphorus flux from sediments due to increases in the diffusional path length. A model such as that of Klapwijk3) is required to assess the actual impact.

Nitrification of sewage treatment plant effluents will cause an addition of nitrate to the Harbour, causing an indirect treatment source for the sediments. Other sources of nitrate addition involve the direct addition of nitric acid or sodium nitrate. The environmental consequences of these treatments are reviewd elsewhere (e.g., Beak, 1987 for Bay of Quinte).11)

3.3.2 - Treatment of Harbour Sediments

a) *Lime Treatment and its Effectiveness*

Lime treatment of harbour sediments would be more effective to precipitate iron, copper, lead and zinc than undertaking that treatment in a water column. Sealing the sediments with lime would prevent toxic metals from re-entering the water column. Periodic treatment of the water column with lime for aesthetic reasons would ultimately provide a physical and chemical barrier to seal the sediments. Thus, lime treatment would be the most effective means of controlling sediment pollutants without causing other side effects1). The advantages and disadvantages of this methods and others is shown in Table 3.8b.

The major disadvantage of the method is that lime precipitation does not lower phosphorus and metal concentrations as much as iron and aluminum salts. This has resulted in these other salts being preferable.

b) *Nitrate Injection and its Effectiveness*

Direct injection of nitrate into the sediments would result in oxidation of the sediment and satisfy some of the sediment oxygen demand. This action will reduce the oxygen demand in the overlying water by the sediment. Oxidation of ammonia to nitrate by the nitrifying bacteria in the sewage treatment plant would be a good source of nitrate for the sediment treatment. The cost of direct application of nitrate to the sediment compared to its cost of discharge to the water column may outweigh any advantages of direct sediment treatment.

c) *Dredging and Disposal and its effectiveness*

Dredging could be carried out selectively to remove the most contaminated areas or carried out over the whole Harbour. Harbour sediments could be physically removed from the Harbour bottom by dredging. Disposal of dredged sediments could be by deep water disposal, landfilling, solidification in place or upland disposal for recreation purposes.

Dredging and physical sealing are the two methods available which can insure removal of toxics and contaminants from the sediments, one of the main goals of the stakeholders. However, the Harbour is a depositional basin in which most

ASSESSMENT OF PROPOSED REMEDIAL ACTION PLANS FOR HAMILTON HARBOUR
ADVANTAGES AND DISADVANTAGES OF EACH MITIGATIVE MEASURE FOR HAMILTON HARBOUR FOR THE SELECTED END USE - HARBOUR SEDIMENT TREATMENTS
TABLE 3.8b

MITIGATIVE MEASURE	SPECIFIC\OTHER ADVANTAGES	OVERALL ADVANTAGES	DISADVANTAGES
SEDIMENT TREATMENT			
1. Dredging and Disposal		- reduce sediment oxygen demand to the hypolimnion	1.-affect harbour water quality -resuspend sediment and cause turbidity in harbour water -increase ammonia and phosphorus levels in harbour waters -increase algal growth and oxygen demand in water column -increase metal and other pollutant concentrations in harbour water -require land for sediment disposal -expensive disposal costs
2. Physical Sealing of Sediments with clay		- reduce sediment oxygen demand to the hypolimnion	2.-resuspension of clay into harbour water turbidity problem in harbour water due to clay suspension
3. Lime Treatment		-economical -reduce sediment oxygen demand to the hypolimnion -precipitation of metals -prevent toxic metals and other pollutants from entering the water column -a good means to seal sediment	
. Nitrate Injection		-suppress sediment oxygen demand	4.-phosphorus release
. Define ship lanes away from shallow areas to reduce disruption of bottom sediments		-prevent sediment resuspension in harbour water -maintain water clarity	5.-limited usage of harbour for navigation
Installation of Dykes to Cootes Paradise		-create cells to isolate sources of pollutants -keep carp out of cells -channel pollutants from streams and Dundas Sewage Treatment Plant directly to Hamilton Harbour -increase pollutant loading to harbour	
Stocking and increasing pike population to prey on carp in Cootes Paradise		-pike controls carp population -reduce turbidity in the water due to reduced carp activity	

contaminants may remain stable, trapped in the sediments. Furthermore, dredging might cause a suspension of sediments in the water column during dredging activity. The role of sediments and their ultimate burial in contamination of biota is a complex issue which has not been adequately researched and resolved. Such resolution is beyond the scope of this report. Accordingly, where necessary, assumptions are made to achieve finalization of this study.

d) *Physical Sealing and its Effectiveness*

Physical sealing of harbour sediments with clay may be an alternative to dredging. This physical barrier minimizes the return of contaminants to the water column and in addition seals off the sediments from obtaining oxygen from the overlying water. However, clay or similarly small particles could be easily resuspended into the water column causing turbidity problems.

e) *Other Mitigating Measures*

Additional mitigating measures involve enhancing fish habitat in the Harbour, including placement of brush bundles along the northern shore of Burlington; lagoons along the northern shore of Burlington and the Lax property; rubbish and other structures along the Perimeter Road, north shore Burlington, and Lax property; construction of islands in the Grindstone Creek delta, and enhancing of Pike habitat in Grindstone Creek above the Habour water level.

Other mitigating measures involve the addition of beach areas along the Lax property, north shore of Burlington and Beach strip (between Rambo Hager diversion and the Canada Centre for Inland Waters) for swimming end users.

The details of these mitigating measures are described below in the appropriate sections. They are not considered here because they do not have a direct impact upon water or sediment quality.

3.3.3 - Mitigative Measures in Cootes Paradise

Mitigative measures would include dredging sediments in the East Pond, cell separation to isolate waste discharges from fish and bird habitats and the installation of dykes in Cootes Paradise to create cells for isolating sources of pollution. The dykes would keep Carp out of the cells and would channel sediment from streams and the Dundas Sewage Treatment Plant directly to Hamilton Harbour.

Carp cause turbidity by stirring up the bottom sediments and uprooting aquatic plants. Carp can be controlled by stocking Pike which will feed on the young Carp, and by selective fishing pressure using derbies.

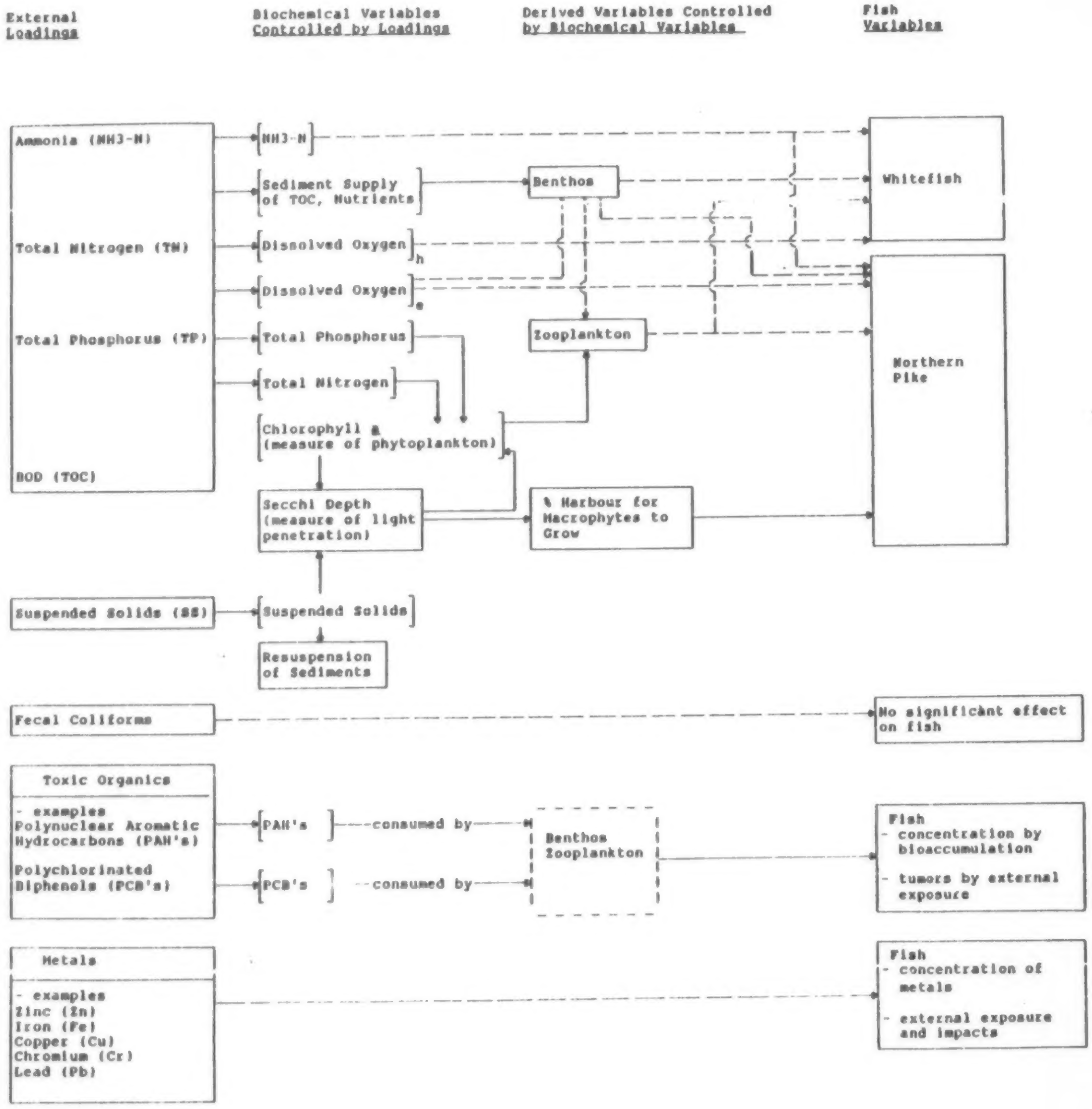
Habitat development would be needed to support a warm water fishery such as Pike and Largemouth Bass. The major habitat proposed in Section 3.6 is a creation of cells for Pike spawning, adult Pike and Largemouth Bass habitat. The impact of these measures on the Harbour's fisheries and their costs have not been estimated before and were developed in this project. Details are given below.

3.4 Cost Effectiveness Analysis for Water Quality

In order to understand the effect of remedial measures upon water quality and on a fishery end use, a set of biophysical linkages is given in Figure 3.1. The headings are related to loadings to the water column and sediment concentrations (biophysical variables controlled by loadings). Several of these biochemical and loading variables [ammonia, (NH_3,); total nitrogen (TN); total phosphorus, (TP); total organic carbon, (TOC); BOD_5, and suspended solids (SS)] have a direct impact upon the fishery habitat for both cold water (Whitefish) and warm water (Northern Pike and Largemouth Bass) species. Of particular concern to this study are two marker variables: dissolved oxygen in the hypolimnion and the fishery habitat for Northern Pike and Largemouth Bass. These two marker variables are used in this study for assessing the impact of mitigating and remedial measures upon the water quality and the fishery of the Harbour.

Other water quality parameters have an influence on the "health" of the ecosystem but do not limit fish habitat. Fecal coliforms are a measure of contamination by fecal matter; they mainly influence the suitability of the harbour for a swimming end use but do not have a significant impact upon fish (except as indicators of possible contamination by viruses, etc.). Toxic organics (e.g., PAH's, PCB's, etc.) and metals will have a direct impact upon fish if they bioaccommulate or cause tumors through external exposure. The precise impact of these variables on a fishery cannot be quantified. However, their concentrations in the Harbour do not appear to limit the fish habitat; rather they mainly influence the edibility of the fish.

FIGURE 3.1 BIOPHYSICAL LINKAGES OF POINT AND NON-POINT SOURCE LOADINGS TO A WARM WATER FISHERY


External Loadings
Biochemical Variables Controlled by Loadings
Derived Variables Controlled by Biochemical Variables
Fish Variables
Ammonia (NH3-N)
Total Nitrogen (TN)
Total Phosphorus (TP)
BOD (TOC)
NH3-N
Sediment Supply of TOC, Nutrients
Dissolved Oxygen h
Dissolved Oxygen e
Total Phosphorus
Total Nitrogen
Chlorophyll a (measure of phytoplankton)
Secchi Depth (measure of light penetration)
Benthos
Zooplankton
% Harbour for Macrophytes to Grow
Whitefish
Northern Pike
Suspended Solids (SS)
Suspended Solids
Resuspension of Sediments
Fecal Coliforms
No significant effect on fish
Toxic Organics
- examples
Polynuclear Aromatic Hydrocarbons (PAH's)
Polychlorinated Biphenols (PCB's)
PAH's
PCB's
consumed by
consumed by
Benthos Zooplankton
Fish
- concentration by bioaccumulation
- tumors by external exposure
Metals
- examples
Zinc (Zn)
Iron (Fe)
Copper (Cu)
Chromium (Cr)
Lead (Pb)
Fish
- concentration of metals
- external exposure and impacts

3.4.1 - Concept of Cost Effectiveness

Classical cost benefit analysis requires that the cost of a particular set of mitigating/remedial measures and their associated benefits be quantified in monetary terms (e.g., dollars). In various areas of environmental analysis, application of cost benefit analysis is fraught with difficulties. The costs are imperfectly known, cost curves are discontinuous due to various technologies being used sequentially for control of loadings, and benefits cannot be quantified. In many instances, not only are the benefits non-quantifiable but also the benefits can only imperfectly be identified. The cost-benefit framework being established in this study for Hamilton harbour is an example of these difficulties.

In this section, an approach of cost-effectiveness is taken as the key link for relating the cost of remedial/mitigating measures to the associated benefits. Costs are quantified in monetary terms while benefits are expressed as an improvement in water quality and increment in littoral habitat for a warm water fishery (using Northern Pike and Largemouth Bass as the example species). This approach limits the ability to place benefits in a monetary framework but it makes the analysis quantitatively tractable and defensible. The end point of the analysis is a biochemical/biophysical set of variables, with dissolved oxygen as an indication of water quality and percent of potential area of fish habitat as an indication of a fishery use. These variables can be quantified with a set of mathematical tools whose predictive ability for describing the ecosystem have been tested. Attempts to extend the analysis into the area of soft costs (benefits) can be accomplished only with tools whose predictions have not been similarly validated.

In a following section 3.5, this cost-effectiveness analysis is extended to include an assessment of a self-sustaining, warm-water fishery. There the littoral habitat is extended to include questions of hatching, rearing and living habitat for Pike and Bass and to give estimates of yield.

3.4.2 - Methods

The end product of a cost effectiveness analysis is a curve or set of curves relating change in resource quality or use versus the costs of attaining the resource. The key to developing such curves is the relationship between the remedial or mitigating measure and the change in water quality. An assessment of the effects of remedial measures requires an evaluation of how the loadings of various pollutants to the water body have been altered. For mitigating measures, there are two different types of linkage to water quality requiring assessment: For those mitigating measures which occur internally within the water body such as oxygenation, there is a direct linkage to water quality. For those mitigating measures which occur external to the water body (such as establishment of hatchery areas for a fishery), there is no direct linkage to water quality.

The following steps are required to develop cost-effectiveness curves.

(i) Development of a strategy for considering various combinations of remedial measures and mitigating measures.

(ii) Evaluation of changes in loadings due to control of point or diffuse sources (remedial measures).

(iii) Evaluation of change in water quality caused by each remedial/mitigating measure.

(iv) Evaluation of costs of the various measures.

(v) Evaluation of change in fisheries habitat due to change in water quality.

(vi) Formulation of cost-effectiveness curves.

The data for steps (ii) and (iv) are available from the literature were summarized earlier in this section (Tables 3.3 and 3.4).

Various strategies for remedial and mitigating measures are given in Table 3.9 together with the cumulative annual cost for the specified sequences of remedial and mitigating measures. The annual costs are estimated assuming a 12% discount rate for amortizing the capital costs over either a 10 or 20 year period. Four strategies for remedial and mitigating measures are considered:

(i) control of the Hamilton sources (including the sewage treatment plant and the combined sewer overflows, see Table 3.9a);
(ii) control of the Burlington Sewage Treatment Plant (see Table 3.9b);
(iii) control of the Industrial Sources (see Table 3.9c);

SCENARIO I CONTROL HAMILTON WASTE EFFLUENT

TABLE 3.9a

Control Number	Description	Capital (million$)	O & M	Cumulative Annual Cost ($million) 10 year Amoritization
1.	Initial	-	-	-
2.	Chemical Precipitation - HWSTP	-	$ 50,000	0.05
3.	Nitrification - HWSTP	3	$350,000	0.931
4.	Sand Filters - HWSTP	35	$ 80,000	7.2
5.	Dual Point Chemical Addition - HWSTP	1	$ 30,000	7.4
6.	Retention Basins	60	$500,000	18.5
7.	Discharge to Lake Ontario	26	$100,000	23.2

SCENARIO II CONTROL BURLINGTON WASTE EFFLUENT

TABLE 3.9b

Control Number	Description	Capital (million$)	O & M	Cumulative Annual Cost ($million) 10 year Amoritization
1.	Initial	-	-	-
2.	Nitrification	6	$100,000	1.20
3.	Sand Filters	9	$ 30,000	2.80
4.	Dual Point Chemical Addition	1	$ 50,000	3.00
5.	Discharge to Lake Ontario	10	$100,000	4.90

SCENARIO III CONTROL INDUSTRIES WASTE EFFLUENT

TABLE 3.9c

Control Number	Description	Capital (million$)	O & M	Cumulative Annual Cost ($million) 10 year Amoritization
1.	Initial	-	-	-
2.	Dofasco Recycle	9	$ -	1.60
3.	Dofasco to HWSTP	0.1	$ -	1.61
4.	Stelco (Work in Progress)	4	$ -	2.30

SCENARIO IV OVERALL CONTROL OPTIONS
TABLE 3.9d

Control Number	Description	Capital (million$)	O & M	Cumulative Annual Cost ($million) 10 year Amoritization
1.	Initial	-	-	-
2.	Chemical Precipitation - HWSTP	-	$ 50,000	0.05
3.	Nitrification - HWSTP	3	$ 350,000	0.931
4.	Nitrification - BSTP	6	$ 100,000	2.1
5.	Dofasco Recycle	9	$ -	3.7
6.	Dofasco to HWSTP	0.1	$ -	3.71
7.	Stelco (Work in Progress)	4	$ -	6.0
8.	Diffuse Source Control	-	$1,500,000	7.5
9.	Sand Filters HWSTP	35	$ 80,000	13.8
10.	Dual Point HWSTP	1	$ 30,000	14
11.	Sand Filters BSTP	9	$ 30,000	15.6
12.	Dual Point BSTP	1	$ 50,000	15.9
13.	Natural Control	-	$ -	15.9
14.	Retention Basins (CSO)	60	$ 500,000	27
15.	Oxygen Injection	0.17	$ 360,000	27.4
16.	Dundas STP	3	$ 50,000	27.6
17.	Dredge Cootes Paradise	4	$ -	28.2
18.	Discharge to Lake Ontario	36	$ 200,000	34.8

HWSTP - HAMILTON-WENTWORTH SEWAGE TREATMENT PLANT

BSTP - BURLINGTON SEWAGE TREATMENT PLANT

CSO - COMBINED SEWER OVERFLOWS

(iv) control of all point and non-point sources and internal sources (see Table 3.9d). A description of each mitigating/remedial measure is given below in Section 3.4.4.

Ideally, in developing these strategies, the following approach would be used for determining the best strategy for selecting the sequence of remedial and mitigating measures.

(i) Evaluate the efficiency of different technologies for removal of each pollutant from each point source, and for reduction of each pollutant discharged by diffuse sources.

(ii) Evaluate the cost of each technology.

(iii) Evaluate the influence of mitigating measures upon the pollutant and the associated costs.

(iv) Develop an abatement cost function for each source of a pollutant (remedial measures) and for appropriate mitigating measures.

(v) Develop an abatement cost function for each pollutant for the whole Harbour using least-cost (cost-minimization) techniques.

It was not feasible to follow these idealized set of steps in this study for the following reasons.

(i) Abatement functions which give a continuous representation between efficiency of removal and cost of treatment for a specific control technology are not appropriate for many of the point sources. Rather, removal of a pollutant occurs by application of a sequence of different control technologies; this gives a discontinuous set of abatement functions consisting of several step functions.

(ii) Least-cost minimization techniques are difficult to apply to Hamilton Harbour. Abatement cost functions normally consist of the cost of abatement versus reduction of loading of one particular water quality parameter. But to achieve the objective for a cost-effectiveness analysis of this section, costs must be related to improvement in water quality and fisheries habitat. For this, control of more than one pollutant (ammonia and phosphorus) must be evaluated. Accordingly, cost abatement functions must be related to more than one pollutant. This is difficult to do because the effect of one unit of phosphorus loading is different than the effect of one unit of ammonia loading. Furthermore, there will be a second order interaction in the effect of these two variables on water quality.

Cost abatement functions can be developed if a different measure than reduction in loading is used to describe effectiveness. A more appropriate measure of effectiveness is "water quality improvement". This requires the use of the nutrient-biomass simulation model. Its application for developing least-cost curves was beyond the resources available to the project.

In this study, a qualitative evaluation of the increment in water quality per unit cost increment was used in selecting the strategy for selection of, and the sequencing of remedial and mitigating measures.

The change in water quality and fisheries habitat was calculated using a nutrient-plankton biomass model previously applied to Hamilton Harbour (Snodgrass and Ng, 1985). The fisheries habitat was assessed by using the littoral area of potential fisheries habitat along the North Shore of Burlington around to the RHYC marina and their relationships to depth of light penetration as calculated by this model.

A better nutrient biomass model would include the modelling concepts of Klapwijk and Snodgrass (1986) and OME (1986). The Klapwijk model is better for describing ammonia transformations, lake-bay exchange, and sediment-water exchange of ammonia, nitrate and oxygen, because these transformations have been analysed in more depth and this model is calibrated with a more extensive set of laboratory and field based calibration. It includes algai decay, but it does not predict changes in plankton biomass which occur due to changes in nutrient loadings. This later relationship necessitates the use of the Ng's model. Ideally, the two models should be combined; but this is beyond the scope of this project. Accordingly, the calculations of the Ng's model are used in this project as an indicator of improvements in water quality and fisheries habitat.

3.4.3 - Water Quality Related Measures of Effectiveness

Two parameters are chosen for evaluating water quality related "effectiveness" in this study: dissolved oxygen in the hypolimnion and percent of the potential littoral fish habitat.

Dissolved oxygen in the hypolimnion is a master variable indicating the health of the ecosystem. Without adequate oxygen, the hypolimnetic waters are, effectively, toxic to many biological organisms or at least stressful to others. Indirectly a lack of oxygen may eliminate some organisms, allowing a shift of the ecosystem towards a less diverse system. It is a prime water quality variable used for managing various resources. It has a significance influence on fish management. It does not, however, have a significant impact on Northern Pike and Largemouth Bass, the targetted species of this analysis, because the prime habitat of these fish is the warm littoral regions of epilimnetic waters. It will, however, have a substantial influence upon the habitat of cold water fish such as ciscos and white fish which are able to inhabit hypolimnetic waters.

Potential littoral fish habitat is used in this project as a second measure of water quality because it describes water clarity and influences the habitat of the warm-water fishery. Of the main use of the Harbour (contact and non-contact recreation, fishing, education, wildlife, water transport, wastewater disposal), a warmwater fishery was identified by the Stakeholders at the Initiation Meeting of September 1, 1987, as a use with which everyone was in general agreement as a priority use. Because a warm-water fishery is a use which generally encompasses the water quality required for other high quality uses, water quality variables which influence the fishery were chosen as the second measure of "effectiveness" considered in this Section.

Different parameters could be used as a surrogate for describing the warm water fishery. Selection of the appropriate parameter depends upon the type of fishery desired. The different types of fishery include:

(i) Self-sustainable, edible warm-water fishery;
(ii) edible, warm-water fishery (maintained by a hatchery production); and
(iii) warm water fishery.

There is a substantial difference between whether the fishery is self-sustainable or not self-sustainable. Factors which influence whether or not the fishery is self-sustainable include predators present in the food chain, availability of appropriate spawning conditions/type of substrate, area of riverine habitat, management of fishing during spawning runs, and fishing pressure. Fishing pressure, which is often a prime factor in fish management, may prevent establishment of a self-sustaining fishery.

The edibility of fish is mainly of concern for human health. The accumulation of unacceptable levels of heavy metals, toxic organics, and pathogenic bacteria or viruses would mandate that the fish not be consumed. Such accumulation would only allow a put-and-take sport fishery.

It was agreed, after discussions with Environment Canada and Department of Fisheries and Oceans personnel, to use littoral fish habitat for Northern Pike and Largemouth Bass as the measure of the warm water fishery. Other factors of importance, including the potential yield of the fishery and whether the fishery is self-sustaining or maintained by hatchery spawning are described later in Section 3.5.

The edibility of the fish is particularly water quality dependent. There is some data available for the contaminants/toxics concentrations in the Harbour water, biota and sediments. An improvement in the data has been generated by the MOE but is not available for this study. Hence, a limited assessment is made in Section 3.6.

For selection of an indicator fish species, a species other than Northern Pike or Largemouth Bass may be more water quality dependent. An listing of fish which inhabit the Harbour are given in Table 3.10a. The general habitat requirements for possible indicator fish species are given in Table 3.10b. In general, fish can be divided into cold water and warm water species. Warm water fish are those which occupy warm epilimnetic waters during the summer (i.e., 18°C - 22°C) while cold water fish are those which occupy colder, hypolimnetic waters (range of 4°C - 10°C) during the summer. The two main types of cold water fish are the salmonids (colder water, hypolimnetic) and the caregonids (who will tolerate warmer water than the salmondis, but which are still classsified as cold water fish). Trout are a typical fish of the salmonid family while whitefish are a typical species in the coregonids family. These latter two categories of cold water fish would be influenced by improvements in hypolimnetic water quality, particularly improvements in hypolimnetic dissolved oxygen.

Due to the stated stakeholders goal of a warm water fishery, Northern Pike and Largemouth Bass are assessed in this report. The yield of the fishery is assessed in Section 3.5. The influence of organics and heavy metals upon the quality of the fish are considered in Section 3.6.

TABLE 3.10a
LIST OF FISH SPECIES IDENTIFIED IN HAMILTON HARBOUR AND COOTES PARADISE (1984 - 1987)

Fish Species
Petromyzontidae - lampreys • Petromyzon marinus - sea lamprey
Anguillidae - freshwater eels • Anguilla rostrata - American eel
Lepisosteidae - gars • Lepisosteys osseus - longnose gar
Amiidae - bowfins • Amia calva
Clupeidae - herrings • Alosa pseudohargengus - alewife • Dorosoma capedianum - gizzard shad
Salmonidae - whitefishes, ciscoes, salmons, and trouts • Onocrhynchus kisutch - coho salmon • Onocrhynchus tshawytscha - chinook salmon • Salmo gairdneri - rainbow trout • Salmo trutta - brown trout • Salvelinus namaycush - lake trout • Coregonus artedii - lake herring • Couesius plumbeus - lake chub
Osmersidae - smelts • Osmerus mordax - American smelt
Umbridae - mudminnows • Umbra limi - central mudminnow
Esocidae - pikes • Esox lucius - northern pike

TABLE 3.10a

LIST OF FISH SPECIES IDENTIFIED IN HAMILTON HARBOUR AND COOTES PARADISE (1984 - 1987)

Fish Species
Cyprinidea - minnows and carp
• Carassius auratus - goldfish
• Cyprinus carpio - carp
• Notemigonus crysoleucas - golden shiner
• Notropis atherinoides - emerald shiner
• Notropis hudsonius - spottail shiner
• Notropis heterolepis - blacknose shiner
• Notropis heterodon - blackchin shiner
• Notropis cornutus - common shiner
• Notropis chrysocephalus - striped shiner
• Notropis volucellus - mimic shiner
• Pinephales promelas - fathead minnow
• Pinephales notatus - bluntnose minnow
• Semotilus atromaculatus - creek chub
• Rhinichthys atratulus - blacknose dace
• Catostomidae - suckers
• Carpidodes cyprinus - quillback
• Catostomus commersoni - white sucker
• Catostomus catostomus - longnose sucker
• Hypentelium nigricans - norther hog sucker
• Ictiobus cyprinellus - bigmouth buffalo
Ictaluridae - bullhead catfishes
• Ictalurus nebulosus - brown bullhead
• Ictalurus punctatus - channel catfish
• Ictalurus melas - brown bullhead
• Ictalurus natalis - yellow bullhead
• Noturus gyrinus - tadpole madtom
Cyprinodontidae - killifish
• Fundulus diaphanus - banded killifish
Atherinidae - silversides
• Labidesthes sicculus - brook silversides
Gasterosteidae - sticklebacks
• Culaea inconstans - fivespine stickleback
Percopsidae - trout perches
• Percopsis omiscomaycus - trout perch

TABLE 3.10a
LIST OF FISH SPECIES IDENTIFIED IN HAMILTON HARBOUR AND COOTES PARADISE (1984 - 1987)

Fish Species
Cerichthyidae - temperate basses • Morone americana - white perch • Morone chrysops - white bass
Centrarchidae - sunfishes • Ambloplites rupestris - rock bass • Lepomis gibbosus - pumpkinseed • Lepomis macrochirus - bluegill • Micropterus dolomieui - smallmouth bass • Micropterus salmoides - largemouth bass • Poxomis nigromaculatus - black crappie • Poxomis annularis - white crappie
Percidae - perches • Percina caprodes - logperch • Etheostoma nigrum - johnny darter • Etheostoma caeruleum - rainbow darter • Perca flavescens - yellow perch • Stizostedion vitreum vitreum - walleye
Sciaenidae - drums or croakers • Aplodinotus grunniens - freshwater drum
Fifty-nine (59) species were captured in Hamilton Harbour and Cootes Paradise between 1984 and 1987.

TABLE 3.10b
HABITAT REQUIREMENTS FOR VARIOUS FISH SPECIES

Fish Species	Warm or Cold	Habitat Requirements
Smallmouth Bass	Warm	• Littoral, macrophyte growth • Perhaps more riverine than large mouth bass
Largemouth Bass	Warm	• Littoral, macrophyte growth
Northern Pike	Warm	• Littoral, requirements for spawning at ice out in submerged vegetation. Littoral or limnetic, less restricted to weed beds, found in shallower quiet bays.
Ciscos, Whitefish	Cold	• More warm water than Lake Trout, but hypolimnetic.
Whitefish	Cold	• Most important commercial fish in Canada

3.4.4 - Remedial and Mitigating Scenarios

The remedial and mitigating scenarios are listed in Table 3.9 for Hamilton sources (Table 3.9a), Burlington sources (Table 3.9b), Industrial sources (Table 3.9c), and all sources (Table 3.9d). The scenarios listed for overall control of the Harbour (Table 3.9d) include all remedial measures described earlier. The loadings used in the Monte Carlo simulations are given in Table 3.11. Accordingly, only the sequence of scenarios for all sources is described here.

1. ***Initial.*** This is the base case using an estimate of loadings and limnological conditions typical of 1984-1985 to define the characteristics of the Base Case.

2. ***Chemical Precipitation, Hamilton-Wentworth Sewage Treatment Plant.*** This involves the addition of ferric chloride by the steel industries to the sewer system to lower the average total phosphorus discharged by the Hamilton-Wentworth STP from 1.2 mg/L to 0.7 mg/L. The addition is purposeful, and designed to enhance phosphorus precipitation. The cost estimates were arrived at after discussion with Mr. Murray Greenfield of Dofasco.

TABLE 3.11

RANGE OF LOADINGS (kg/day) USED IN MONTE CARLO SIMULATIONS FOR THE EUTROPHICATION SCENARIO

Control Number	Description	Organic N	Ammonia	Nitrate	Total Phosphorus
1	Initial	5400 - 8200	5700 - 8800	4600 - 6800	600 - 900
2	Chemical Precipitation - HWSTP	5400 - 8200	5700 - 8800	4600 - 6800	530 - 790
3	Nitrification - HWSTP	5400 - 8200	1800 - 2700	7800 - 12000	530 - 790
4	Nitrification - BSTP	5400 - 8200	1400 -2200	7800 - 12000	530 - 790
5	Dofasco to Recycle	5400 - 8200	1100 - 1700	7800 - 12000	530 - 790
6	Dofasco to HWSTP	5400 - 8200	1000 - 1600	8100 - 12000	530 - 790
7	Stelco (Work in Progress)	5400 - 8200	1000 - 1600	8100 - 12000	530 - 790
8	Diffuse Source Control	5400 - 8200	1000 - 1600	8100 - 12000	490 - 780
9	Sand Filters HWSTP	5400 - 8200	1000 - 1600	8100 - 12000	320 - 480
10	Dual Point HWSTP	5400 - 8200	1000 - 1600	8100 - 12000	270 - 410
11	Sand Filters BSTP	5400 - 8200	1000 - 1600	8100 - 12000	250 - 380
12	Dual Point BSTP	5400 - 8200	1000 - 1600	8100 - 12000	240 - 360
13	Natural Control	5400 - 8200	1000 - 1600	8100 - 12000	240 - 360
14	Retention Basins (CSO)	5400 - 8200	900 - 1300	8200 - 12000	180 - 270
15	Oxygen Injection	5400 - 8200	900 - 1300	8200 - 12000	180 - 270
16	Dundas STP	5400 - 8200	900 - 1300	8200 - 12000	170 - 250
17	Dredge Cootes Paradise	5400 - 8200	900 - 1300	8200 - 12000	160 - 240
18	Discharge to Lake Ontario	3800 - 5800	300 - 460	920 - 1400	140 - 200

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

3. ***Nitrification, Hamilton-Wentworth Sewage Treatment Plant.*** This involves implementation of nitrification in the Hamilton-Wentworth Sewage Treatment Plant to achieve 90% conversion of ammonia to nitrate.

4. ***Nitrification, Burlington Sewage Treatment Plant.*** This is similar to "Nitrification Hamilton-Wentworth Sewage Treatment Plant" but is applied to the Burlington Sewage Treatement Plant.

5. ***Dofasco Inc., Recycle.*** This involves additional recycle of ammonia in Dofasco Inc. to prevent ammonia discharge to the Harbour.

6. ***Dofasco Inc. to Hamilton-Wentworth Sewage Treatment Plant.*** This involves discharge of the residual ammonia from Dofasco Inc. to the City Sewer system. Nitrification of 90% of the ammonia in the Hamilton Sewage Treatement Plant is assumed.

7. ***Stelco Inc. (Work in Progress).*** This involves general improvements in the Stelco Inc. sewer systems to prevent these discharge to the harbour.

8. ***Diffuse Source Control.*** This involves reduction of phosphorus discharged from agricultural sources. The costing assumes that 230 km^2 of the watershed in row crop production is converted from moldboard plowing tillage to non-plowing tillage. Per acre costs to the farmers were estimated from Bay of Quinte RAP analyses (Appendix A). The reduction in phosphorus loadings is approximately 50 kg/d with this change in practice.

9. ***Sand Filters Hamilton-Wentworth Sewage Treatment Plant.*** This strategy involves implementation of tertiary treatment in the farm of sand filtration at the Hamilton-Wentworth Sewage Treatment Plant to minimize the discharge of phosphorus contained in particulate form. In sewage treatment plants which practise chemical precipitation for phosphorus control, much of the phosphorus discharged is in particulate form, but is not removed by final clarifiers. Sand filters can bring the effluent down to a level of 0.1 to 1 NTU, residual turbidity.

10. ***Dual Point Hamilton-Wentworth Sewage Treatment Plant.*** This involves chemical injection at two points in the Hamilton-Wentworth Sewage Treatment Plant. It is implemented after construction of the sand filters. It provides

additional phosphorus removal by improving the efficiency of making a soluable phosphorus into particles for removal in the sand filters.

11. ***Sand Filters Burlington Sewage Treatment Plant.*** This strategy is similar to Sand Filter Hamilton-Wentworth Sewage Treatment Plant, but is applied to the Burlington Sewage Treatment Plant.

12. ***Dual Point Hamilton-Wentworth Sewage Treatment Plant.*** This strategy is similar to Dual Point Hamilton-Wentworth Sewage Treatment Plant, but is applied to the Burlington Sewage Treatment Plant.

13. ***Natural Control.*** After a decade of improving wastewater treatment, it is plausible that the sediments will burn off much of their oxygen demand and will be buried by new materials which exert a lower sediment oxygen demand (SOD). It is probable that such management could cause SOD to decrease to 30 to 70% of present rates of SOD. The "natural control" option assessed in this reprot assumes a lowering of SOD by 50%. A more sophisticated model for SOD then is currently used is required to improve our confidence in the assumption.

14. ***Retention Basins.*** This strategy assumes the intercepting of storm water runoff by the construction of 12 storage basins on the 12 main Combined Sewer Overflows, which discharge to the Harbour. One has presently been completed in 1986 (Greenhill, which discharges to Red Hill Creek). The costing for this one is applied to the others. The costing does not include extra costs to the Hamilton-Wentworth Sewage Treatement Plant which would result from the additional volume of water being treated. Such costing data have been obtained.

15. ***Oxygen Injection.*** This is a mitigating measure involving direct injection of oxygen to the hypolimnion. It is assumed that injection would occur for the stratified period. It is assumed that this technique would only be applied at this control option; hence, it is not considered as part of the sequence of options 16 to 18.

16. ***Dundas Sewage Treatment Plant.*** There are two options for control of the Dundas Sewage Treatment Plant: routing of its outflow to the Hamilton sewer-system, or improvement of the Dundas Sewage Treatment Plant. This option in this report assumes placement of sand filters and dual point injection in the Dundas Sewage Treatment Plant. It is assumed that the loading reduction at the

Dundas Sewage Treatment Plant causes the same magnitude of reduction in the discharge of total phosphorus to the Harbour. The costs are estimated by scaling down the costs for the Hamilton-Wentworth Sewage Treatment Plant and providing a safety factor of two times to the cost estimate.

17. ***Dredging.*** This option assumes a phosphorus reduction associated with dredging of Cootes Paradise. The loading impact is estimated by partitioning the loadings to Cootes into those derived from point, diffuse, sources and internal loading. Dredging costs are based upon unit costs for Harbour dredging (Hamilton Harbour Commissioners, Personal Communication) and is the value in the Bay of Quinte RAP Report.11)

18. ***Discharge to Lake Ontario.*** This option involves the discharge of wastewater to Lake Ontario from the Hamilton and Burlington Wastewater Treatment Plants. Note, this option ***does not*** involve discharge of surface water streams (Red Hill Creek, etc.) and residual combined sewer/storm discharges to the lake.

3.4.5 - Method for Calculating the Measures of Effectiveness

A) Hypolimnetic Dissolved Oxygen

All mechanisms influencing hypolimnetic dissolved oxygen are included in the model used in this study (see Snodgrass and Ng, 1985). Accordingly, its mathematics are not reproduced here. Rather a brief synopsis of the main mechanisms influencing dissolved oxygen degradation are now presented.

The degradation of hypolimnetic dissolved oxygen is caused by the oxidation of ammonia by nitrifiers, decomposition of organic matter formed as a result of algal biomass and BOD inputs, oxidation of organic sulphur compounds by heterotrophic and other bacteria, and sediment oxygen demand. Oxygen is resupplied to the hypolimnion by transport processes across the thermocline and direct currents from Lake Ontario through the Burlington Ship Canal. Various reactions are temperature dependent.

The concentrations of ammonia in the Harbour results mainly from ammonia loadings from the Hamilton-Wentworth Sewage Treatment Plant but also from decomposition of algae in the Harbour. Organic matter formed from algae is controlled by phosphorus inputs, water temperature, and light penetration which is influenced by water clarity.

B) Potential Macrophyte Habitat

The same model (Snodgrass and Ng, 1985) as used for the calculation of hypolimnetic dissolved oxygen was used to assess potential macrophyte habitat. The model calculates the response of phytoplankton biomass (as characterized by chlorophyll) and offshore water clarity (as characterized by gross light extinction coefficient) to the same scenario sequence of remedial and mitigating measures as used for the hypolimnetic oxygen calculations. To express these calculations in terms of potential macrophytic area, the model was extended to consider Secchi depth and macrophyte growth. These extensions are now described.

There are a variety of measures of macrophyte growth which could have been used in this analysis. (S. Painter, pers. comm.). All are related to the depth of light penetration (i.e. water clarity). They are:

- the maximum depth at which plants will colonize;
- the depth at which maximum biomass will develop; and
- the growth rate of the dominant macrophytic species.

In an ecological sense, the growth rate is a more dynamic measure of the health of the ecosystem than static "depth" measures, and hence is a more desirable variable to be evaluated. However, the variability of growth dynamics and our confidence in the ability of models to calculate the various factors influencing growth are poor. Accordingly, in this work, the maximum depth at which plants will colonize was chosen as the measure of macrophytic response to improvement in water quality. This measure was chosen primarily because:

- there is a literature which describes the relationships of depth of colonization as a function of water clarity which could be used in this study; and
- the present areas of macrophyte growth along the new shore of Burlington (e.g. Lasalle Park area) approximately match these literature values (S. Painter, pers. comm.).

The following relationships were used to extend the model to calculate the response of macrophyte beds to improvement in water clarity:

$$Z_s = \frac{1.12}{0.85E - 0.4} \qquad (1)$$

$$Z_m = (1.33 \text{ Log } (Z_s) + 1.4)^2 \qquad (2)$$

where: E = gross light extinction coefficient (m^{-1})
Z_s = Secchi disk depth (m)
Z_m = depth of maximum macrophyte biomass colonization (m)

The first relationship (Equation 1) is based upon research data gathered from the harbour during 1986 and 1987 field years by V. Cairns, S. Painter and S. Mellard, (pers. comm, and with many thanks). Based upon an overall regression between Secchi disk transparency and extinction coefficient, their relationship for this open-water of Hamilton Harbour is:

$$E = \frac{1.12}{Z_s} + 0.4 \qquad (3)$$

The Equation 1 was adapted in this study from Equation 3 to correct for the calibration of the model which calculates a gross extinction coefficient which is too large by approximately 15%.

The second relationship (Equation 2) is that of Chambers and Kauff (1985). It was based upon data from eight lakes in southern Quebec in which the maximum depth of angiosperm colonization was measured and compared to Secchi disk depth (m) over the growing season). The lakes included a six-fold range in trophy from oligotrophic to eutrophic. The harbour data from 1987 suggest that it behaves similarly. To account for inshore-offshore differences and the relationship of extinction coefficient to inorganic suspended solids, modifying relationships were sought. However, because existing data indicate that habitat in deeper waters will be susceptible to point source control, the relationships given above are retained for this study.

To estimate the area of harbour habitat, the potential habitat in the areas of the Windermere Basin, the eastern shore, Indian Creek, Lasalle Park, Grindstone Creek and Dundurn Park (Perimeter Road, Lax Property to the boat club) were measured at 1m intervals by S. Painter. Assessment of the zones indicated that neither Windermere nor the eastern shore would provide suitable habitat. Accordingly, they were ignored in the assessment. The resulting depths of potential macrophyte development are related to the bottom littoral areas as follows:

Depth	Cumulative Percent of Area
73.7 to 73 m	0
73 to 72 m	22
72 to 71 m	38
71 to 70 m	51
70 to 69 m	60
69 to 68 m	75

The cumulative percentage between 73.7 m and 68 m is 100%; in evaluating the potential area for macrophyte development, it is assumed that macrophytes would not develop in the top 0.7 m (73.7 to 73 m) due to ice effects. This results in approximately 25% of the potential littoral area being unavailable for macrophyte growth.

An additional potential area of macrophyte growth is caused by water level variations. The long-term water level in the Harbour is 74.7 m; this means that the littorial area above 73.7 m will often exist. However, the top 0.7 m would still be devoid of macrophytes due to ice effects. Furthermore, as the calculations indicate below, the total area available for macrophytes will not be occupied due to ice effects. Hence, the data given above are retained for use in this study.

3.4.6 - Results: Cost Effectiveness for Hypolimnetic Dissolved Oxygen

The results of the calculations of effectiveness are given in Figures 3.2 to 3.5 as follows:

3.2a Hypolimnetic DO for control of Hamilton Sources as a function of Control Number.

3.2b Cost (20 Year Amortization) of Improving Hypolimnetic DO by Controlling Hamilton Sources.

3.2c Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling Hamilton Sources.

3.2d Cost (Log Scale; 20 Year Amortization) of improving Hypolimnetic DO by Controlling Hamilton Sources.

3.2e Cost (Log Scale; 10 Year Amortization) of improving Hypolimnetic DO by Controlling Hamilton Sources.

3.3a Hypolimnetic DO as a Function of Control of Burlington Sources.

3.3b Cost (Log Scale; 20 Year Amortization) of improving Hypolimnetic DO by Controlling Burlington Sources.

3.3c Cost (Log Scale; 10 Year Amortization) of improving Hypolimnetic D) by Controlling Burlington Sources.

3.4a Hypolimnetic DO as a Function Control of Industrial Sources.

3.4b Cost (10 Year Amoritization) of Improving Hypolimnetic DO by Controlling Industrial Sources.

3.5a Hypolimnetic DO as a Function Control of all Sources.

3.5b Cost (20 Year Amortization) of Improving Hypolimnetic DO by Controlling All Sources.

3.5c Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling All Sources.

3.5d Cost (Log Scale; 20 Year Amortization) of improving Hypolimnetic DO by Controlling All Sources.

3.5e Cost (Log Scale; 10 Year Amortization) of improving Hypolimnetic DO by Controlling All Sources.

The first figure (Figures 3.2a, 3.3a, 3.4a, 3.5a) of each set of figures (Figures 3.2 to 3.5) details the amount of water quality improvement (as measured by dissolved oxygen) as a function of the control option. The following improvement in dissolved oxygen results for all of the control options considered in each scenario:

Scenario 1: Control of Hamilton Sources : Change in DO_h = 1 mg/L
Scenario 2: Control of Burlington Sources : Change in DO_h = less than 0.5 mg/L
Scenario 3: Control of Industrial Sources : Change in DO_h = less than 0.1 mg/L
Scenario 4: Control of All Sources : Change in DO_h = 3 mg/L

HAMILTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Sand Filters - HWSTP
5	Dual Point Chemical Addition - HWSTP
6	Retention Basins
7	Discharge to Lake Ontario

HAMILTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Sand Filters - HWSTP
5	Dual Point Chemical Addition - HWSTP
6	Retention Basins
7	Discharge to Lake Ontario

Figure 3.2a. Hypolimnetic DO for control of Hamilton Sources as a function of Control Number.

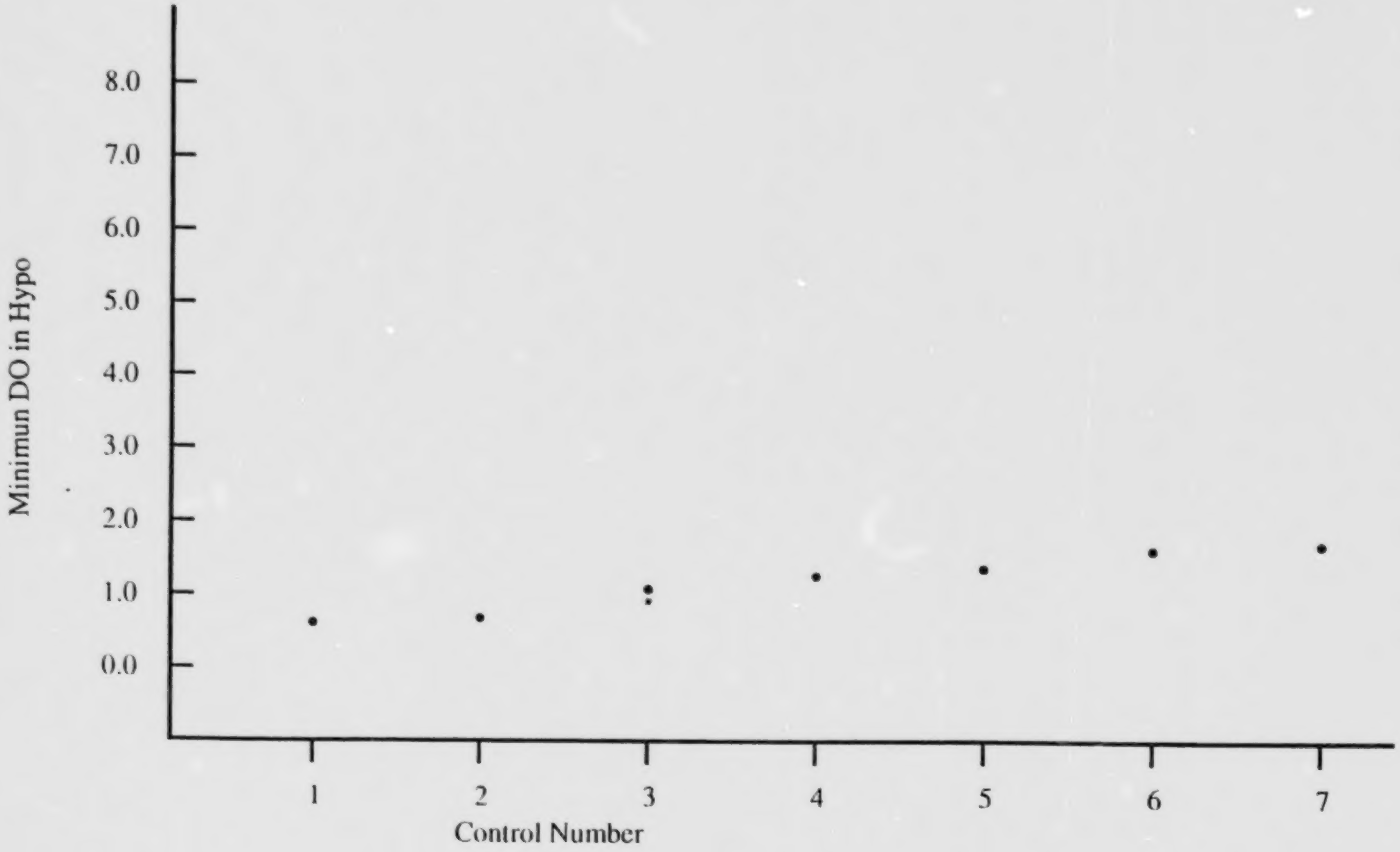
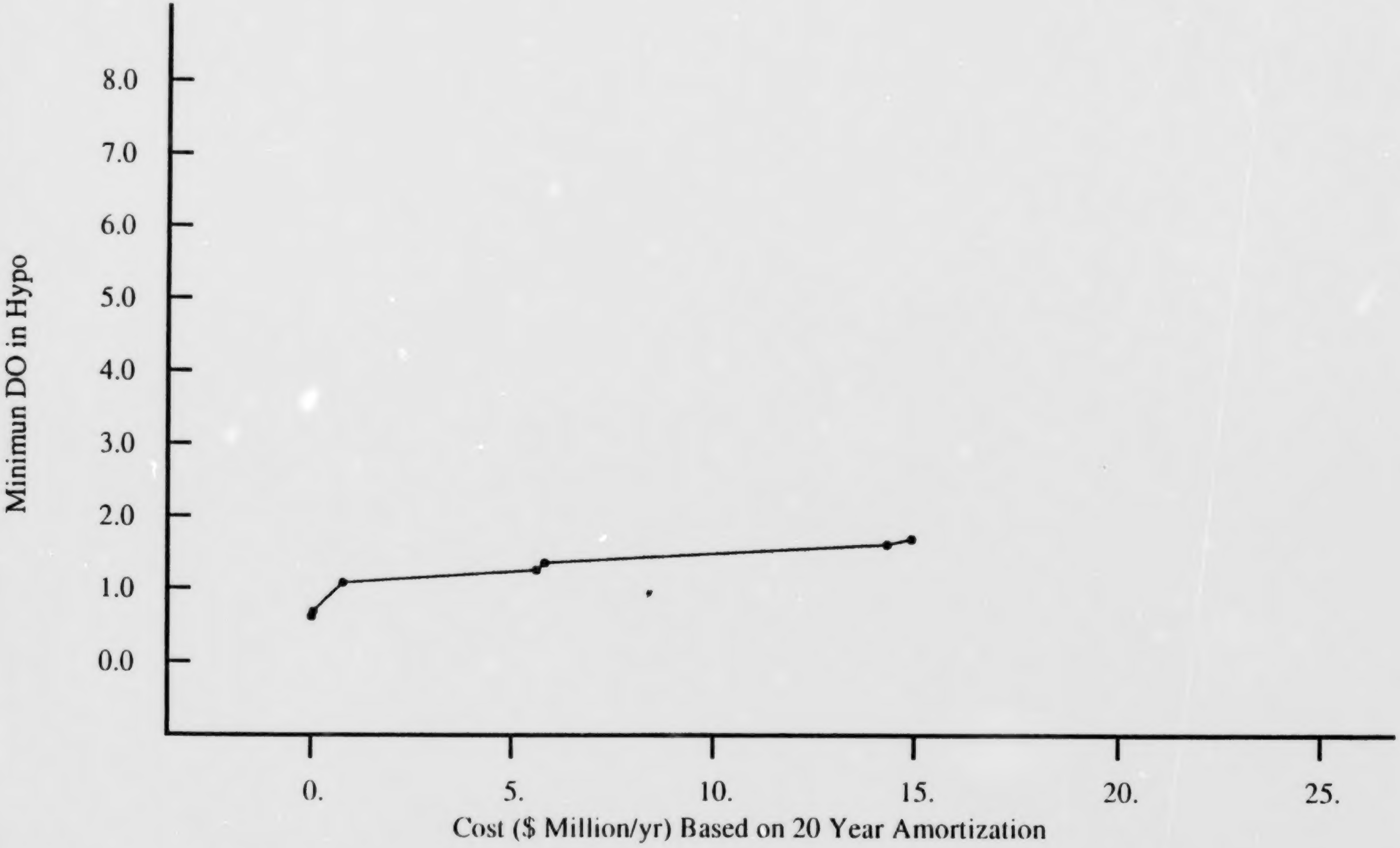


Figure 3.2b. Cost (20 Year Amortization) of Improving Hypolimnetic DO by Hamilton Sources.



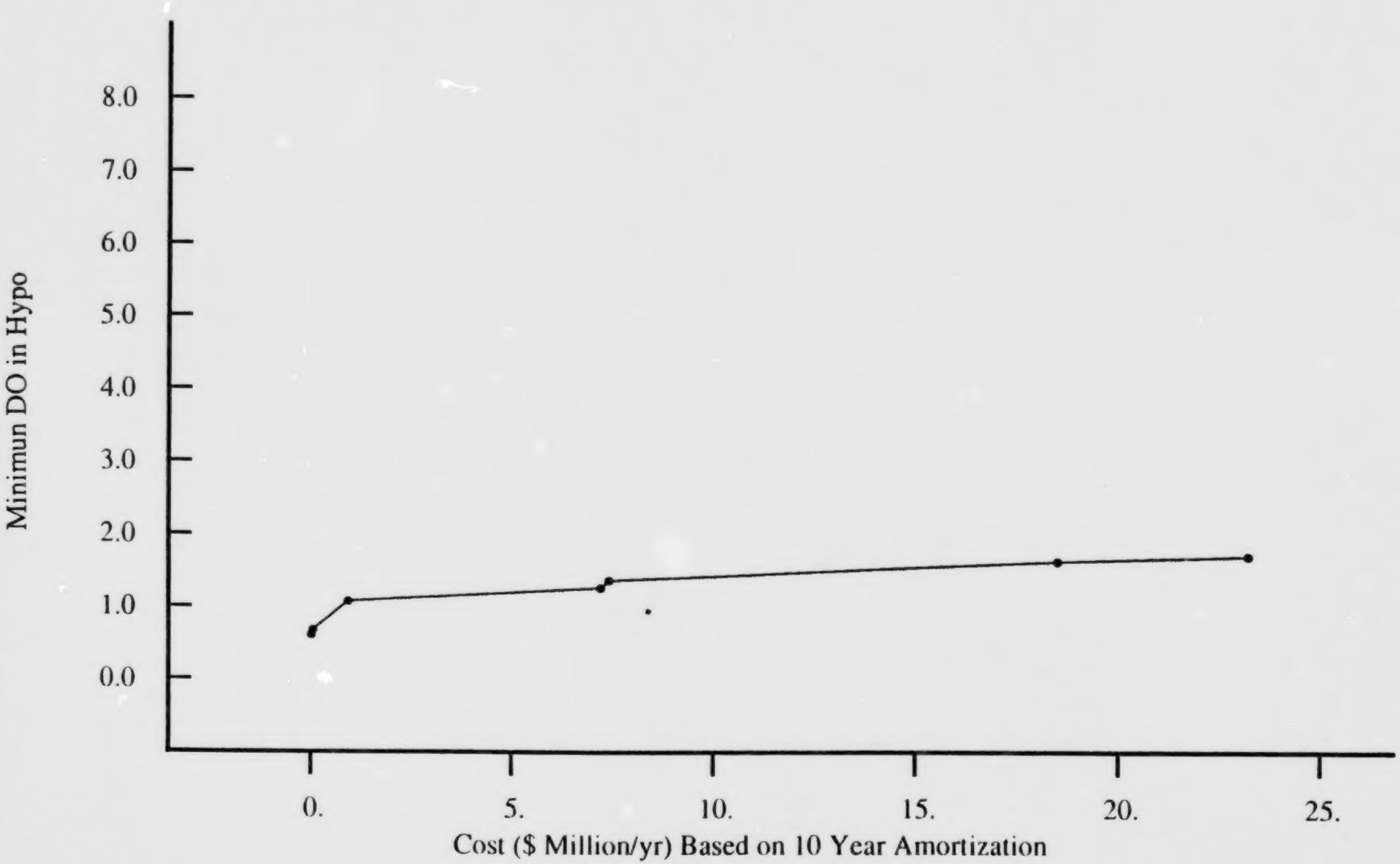


Figure 3.2c. **Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling Hamilton Sources.**

Figure 3.2d. Cost (Log Scale; 20 Year Amortization) of Improving Hypolimnetic DO by Controlling Hamilton Sources.

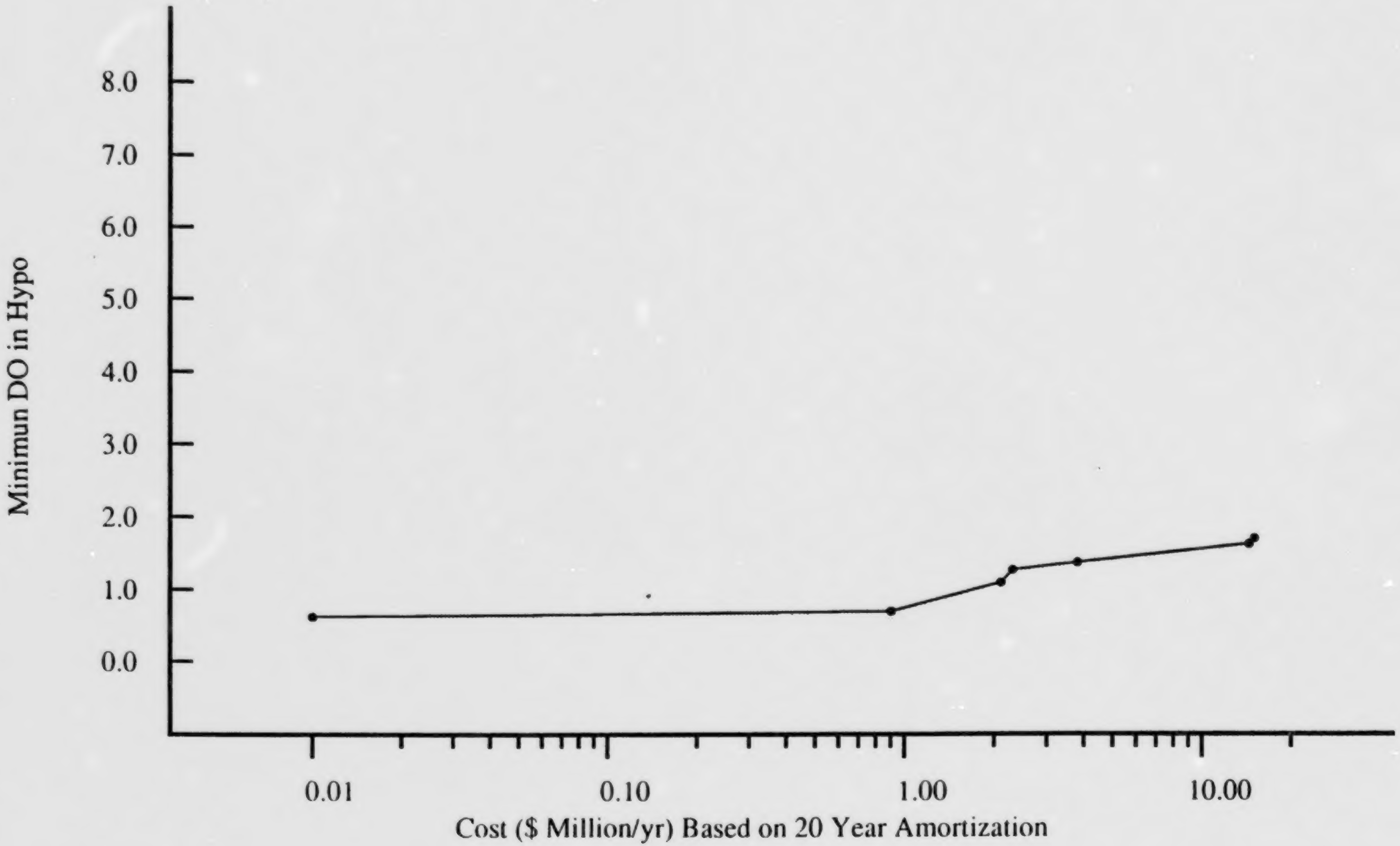
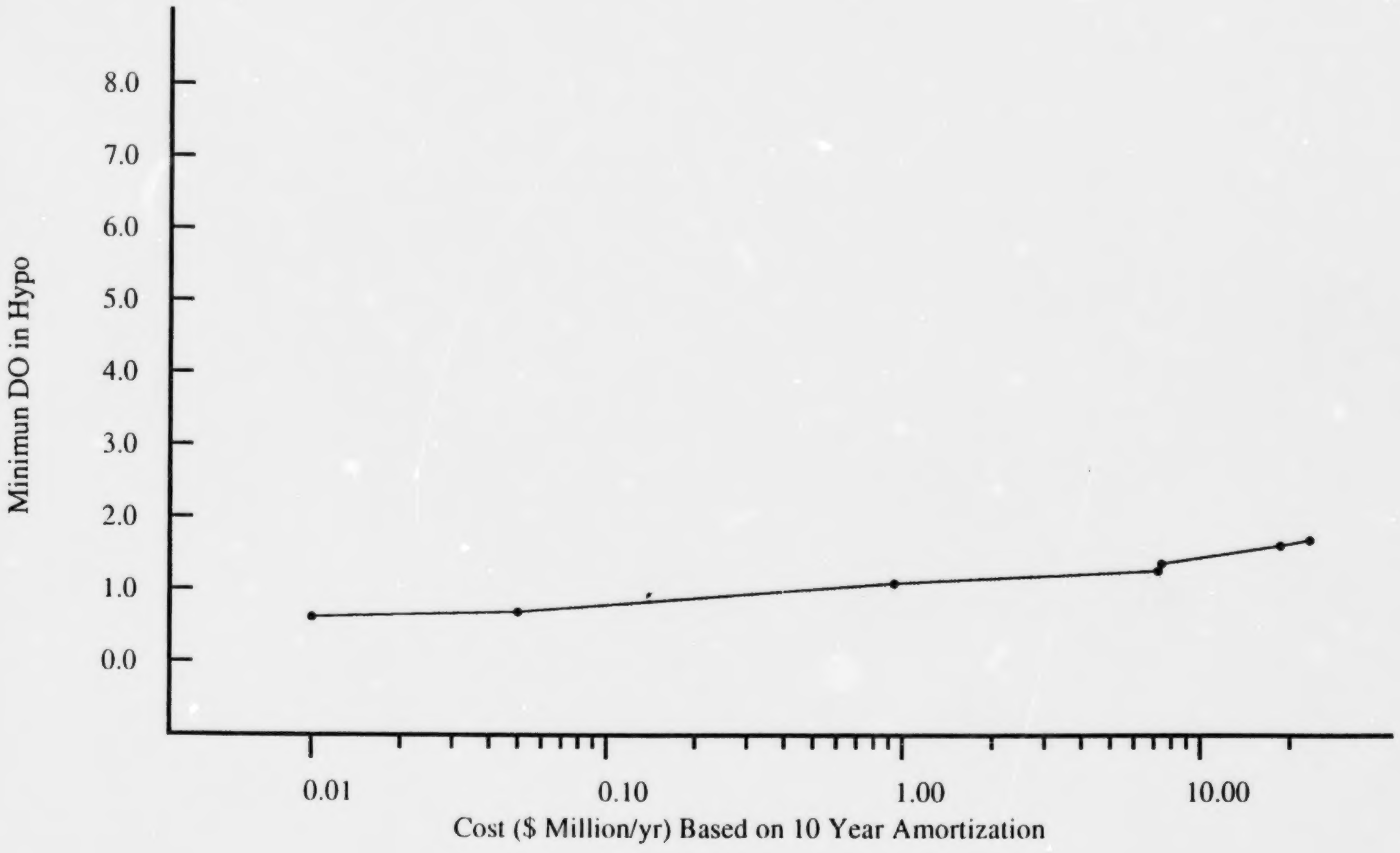


Figure 3.2e. Cost (Log Scale; 10 Year Amortization) of Improving Hypolimnetic DO by Controlling Hamilton Sources.



BURLINGTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Nitrification
3	Sand Filters
4	Dual Point Chemical Addition
5	Discharge to Lake Ontario

BURLINGTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Nitrification
3	Sand Filters
4	Dual Point Chemical Addition
5	Discharge to Lake Ontario

Figure 3.3a. Hypolimnetic DO as a Function of Control of Burlington Sources.

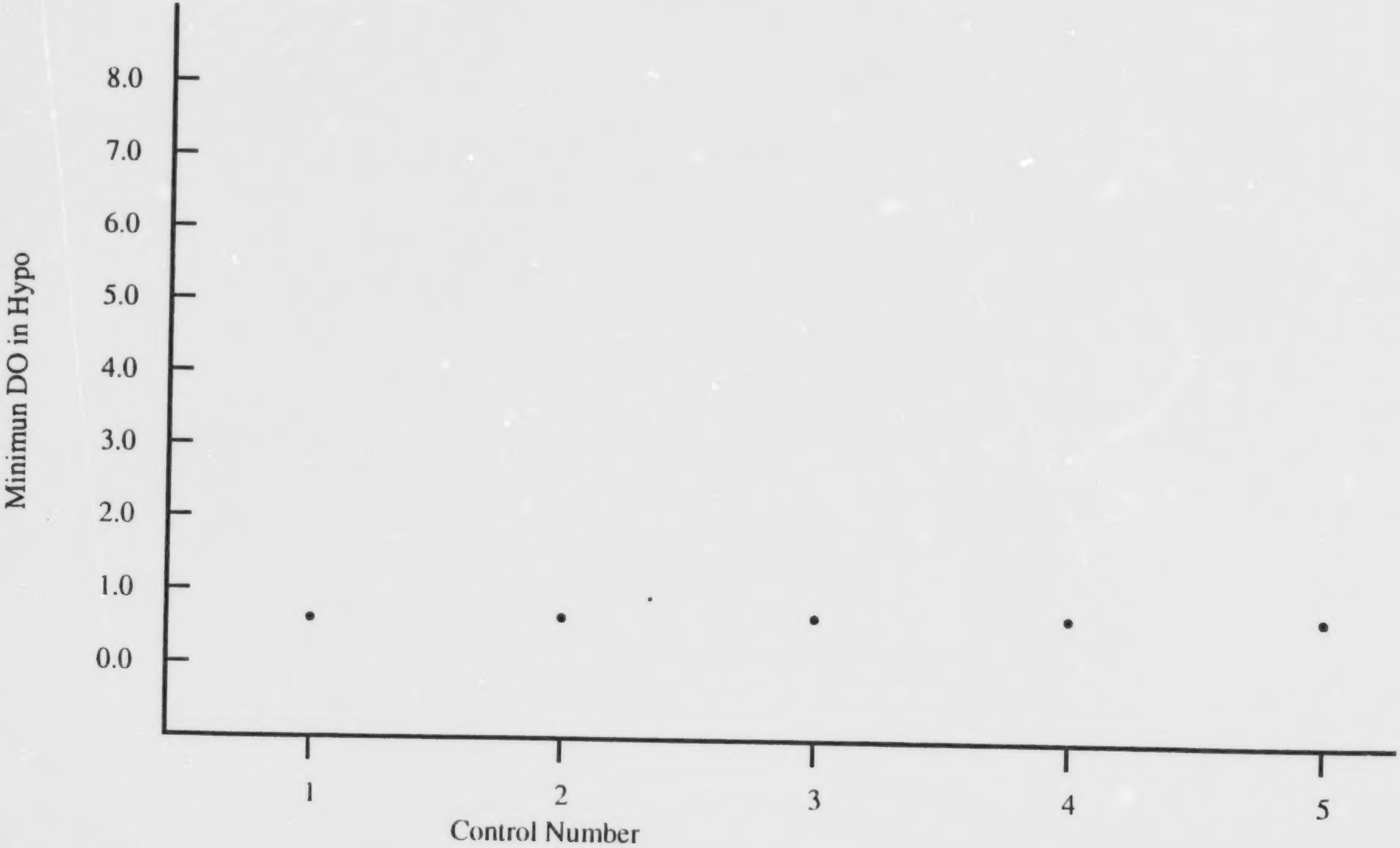


Figure 3.3b. Cost (20 Year Amortization) of Improving Hypolimnetic DO by Controlling Burlington Sources.

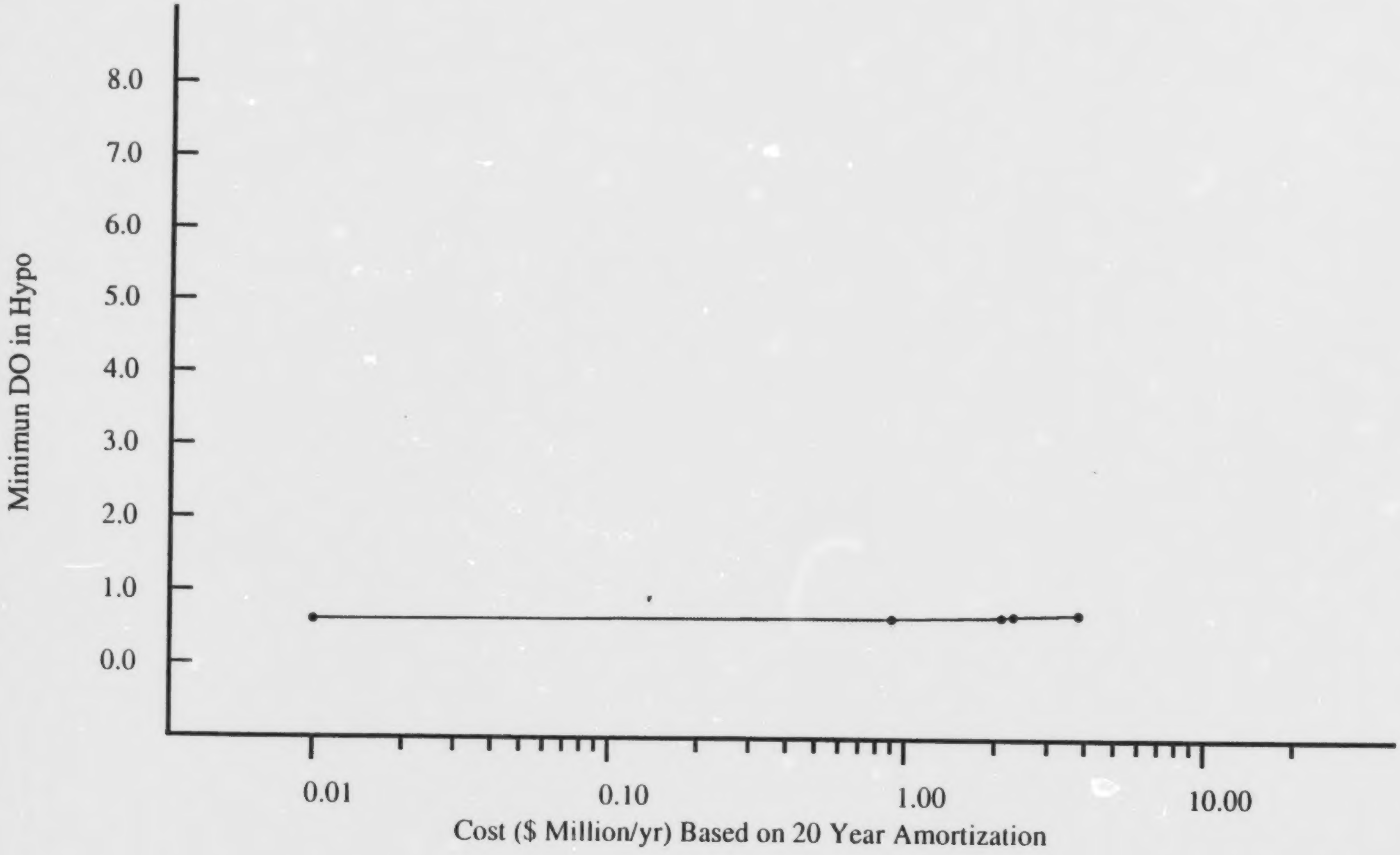
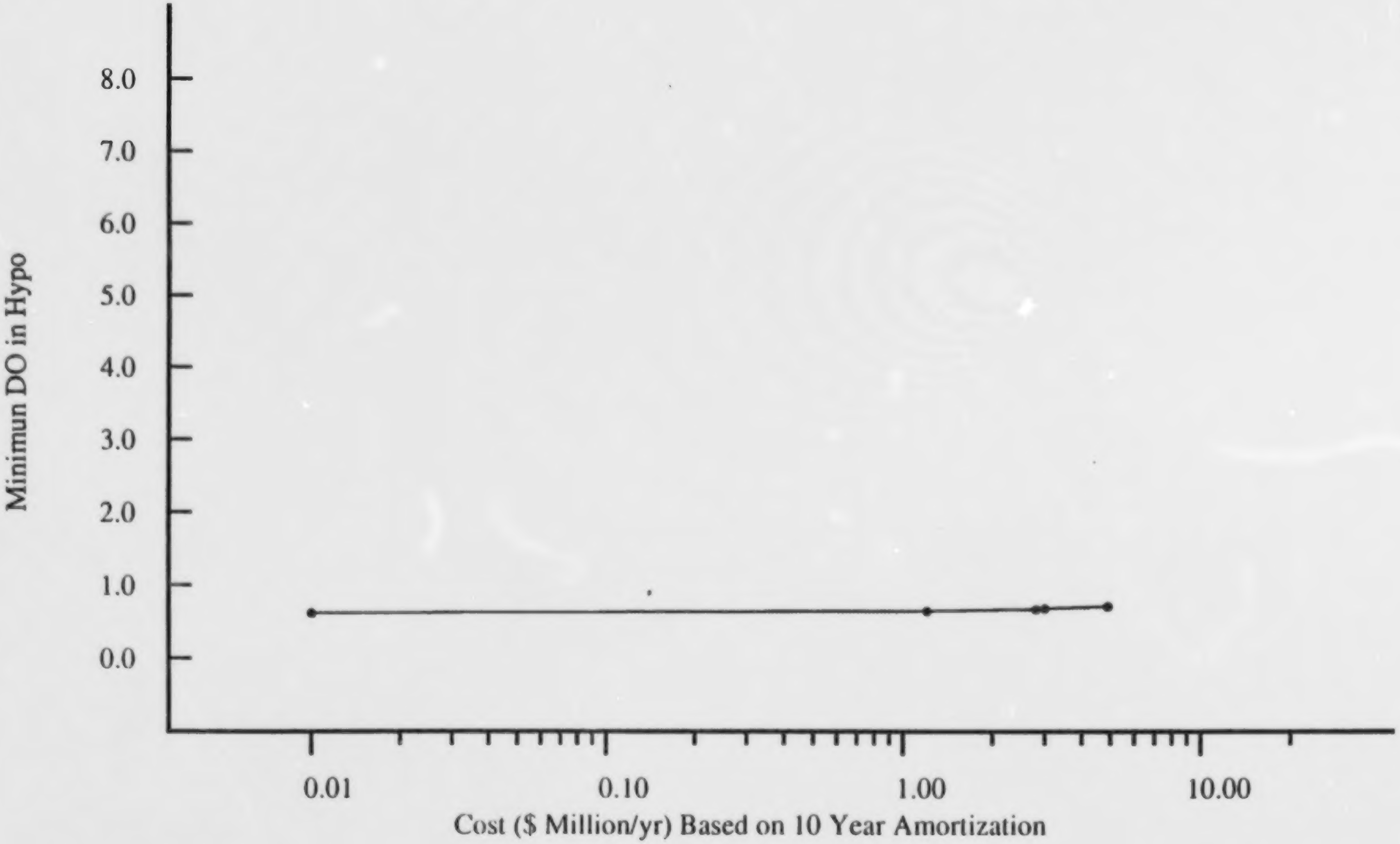


Figure 3.3c. **Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling Burlington Sources.**



INDUSTRIES WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Dofasco Recycle
3	Dofasco to HWSTP
4	Stelco (Work in Progress)

INDUSTRIES WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Dofasco Recycle
3	Dofasco to HWSTP
4	Stelco (Work in Progress)

Figure 3.4a. Hypolimnetic DO as a Function of Control of Industrial Sources.

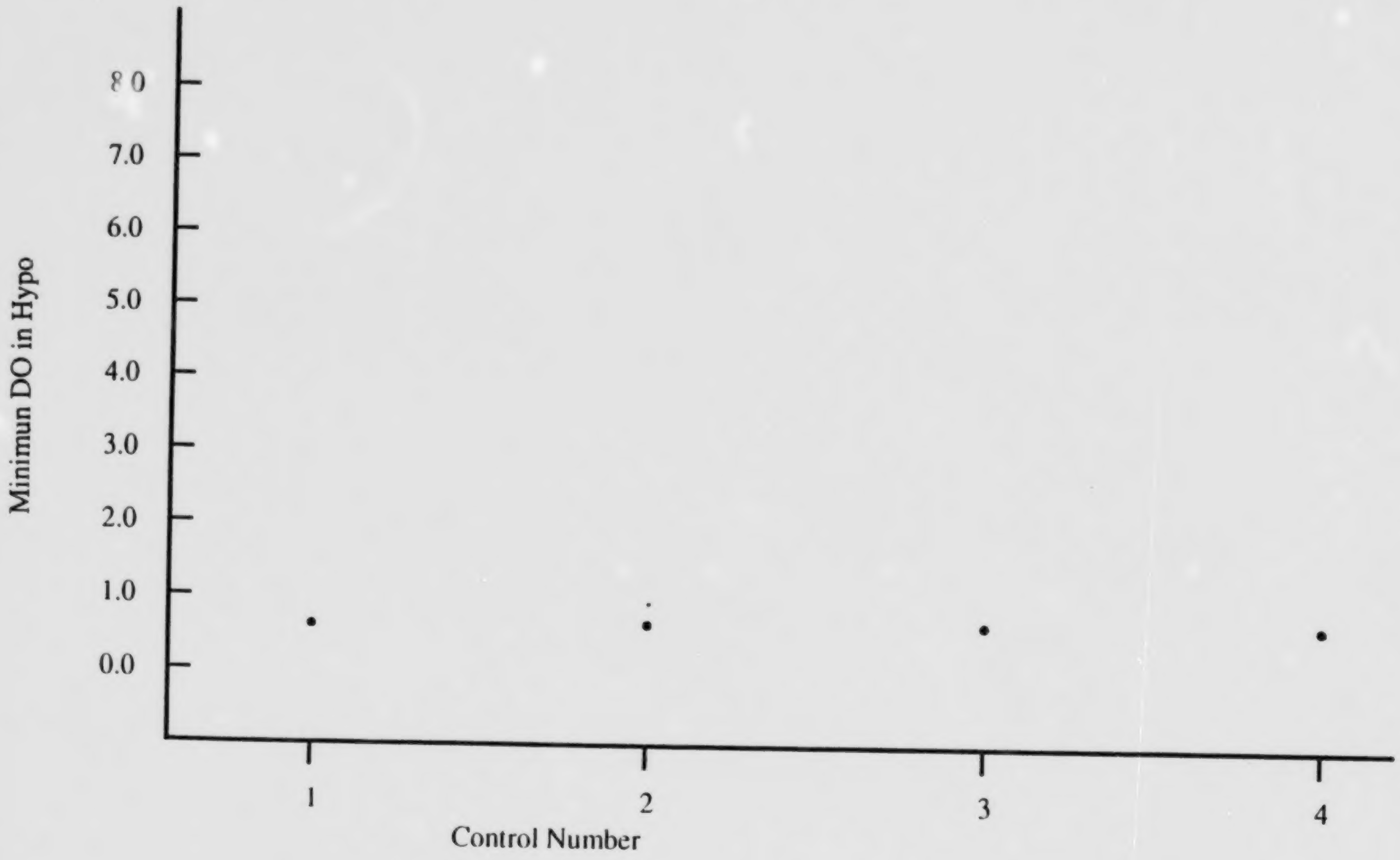
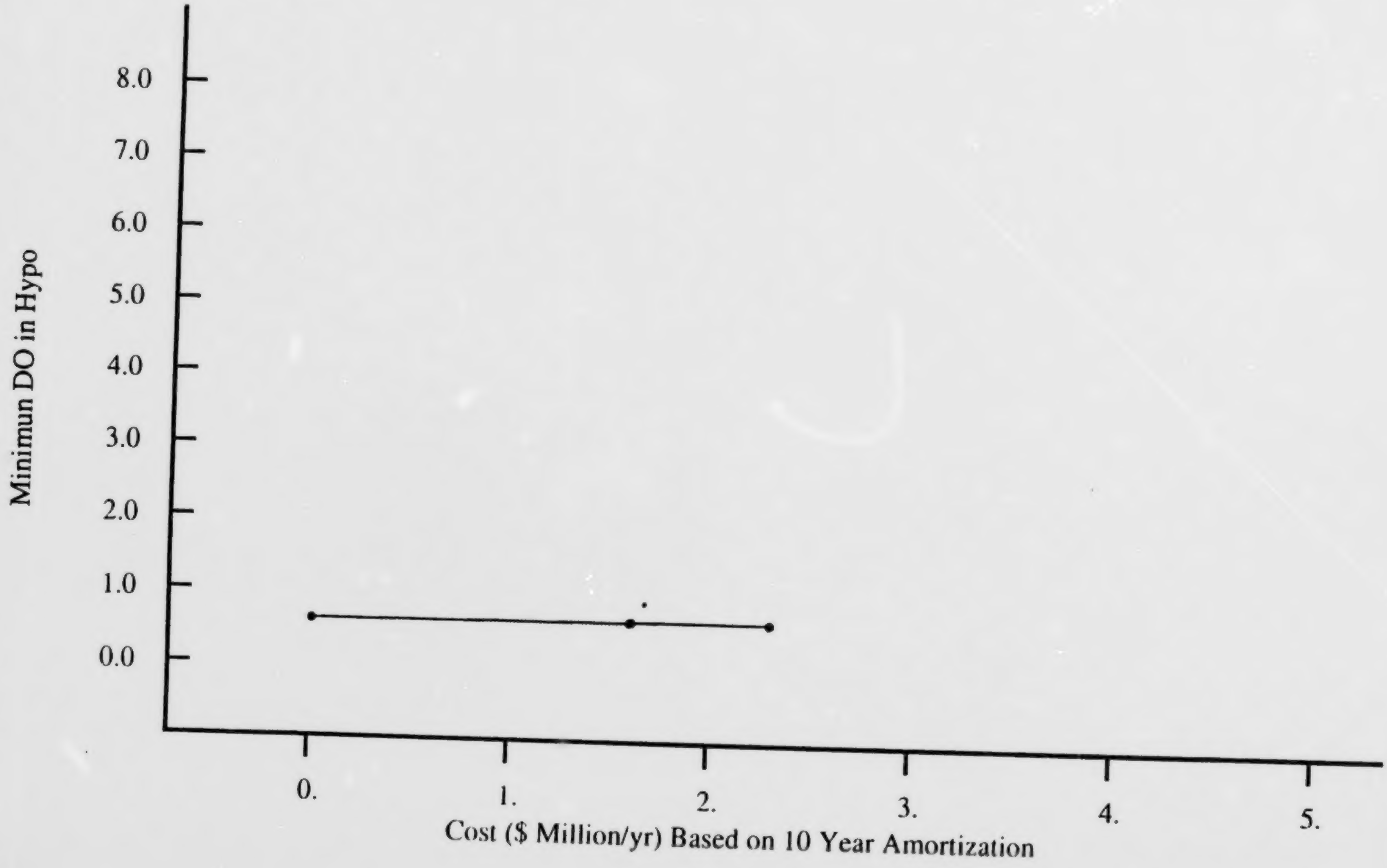


Figure 3.4b. Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling Industrial Sources.



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.5a. Hypolimnetic DO as a Function of Control of All Sources.

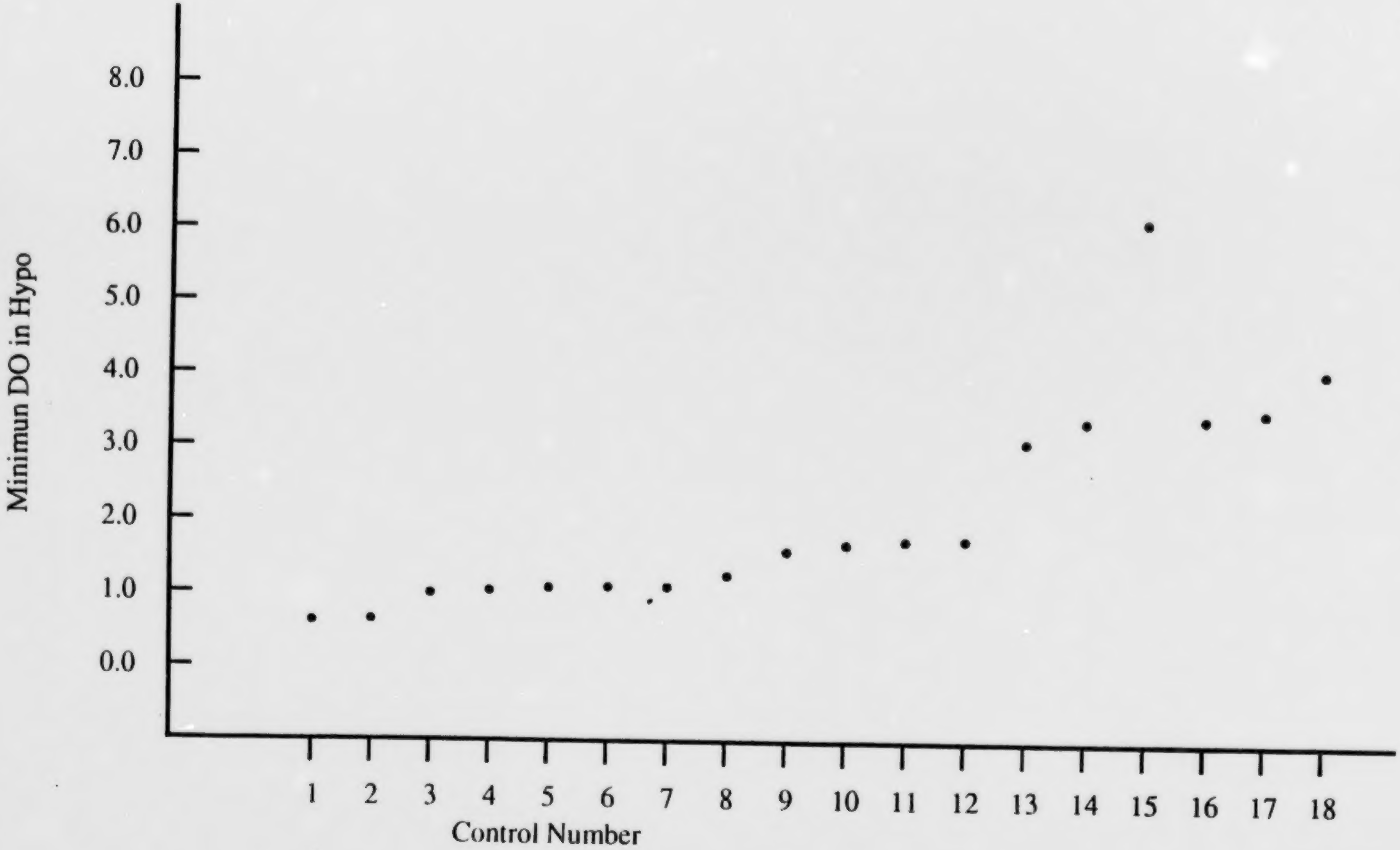


Figure 3.5b. Cost (20 Year Amortization) of Improving Hypolimnetic DO by Controlling All Souces.

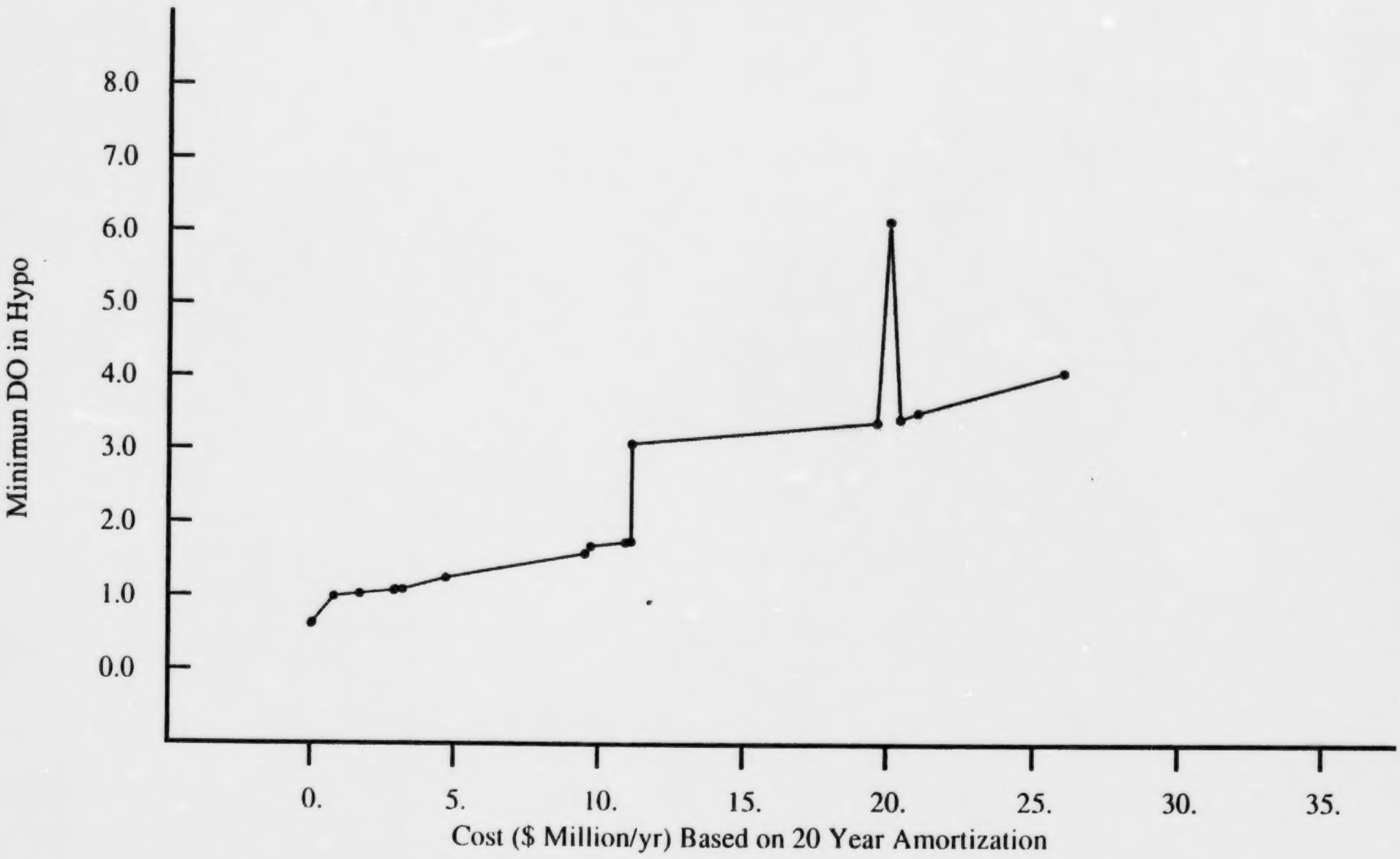


Figure 3.5c. Cost (10 Year Amortization) of Improving Hypolimnetic DO by Controlling All Sources.

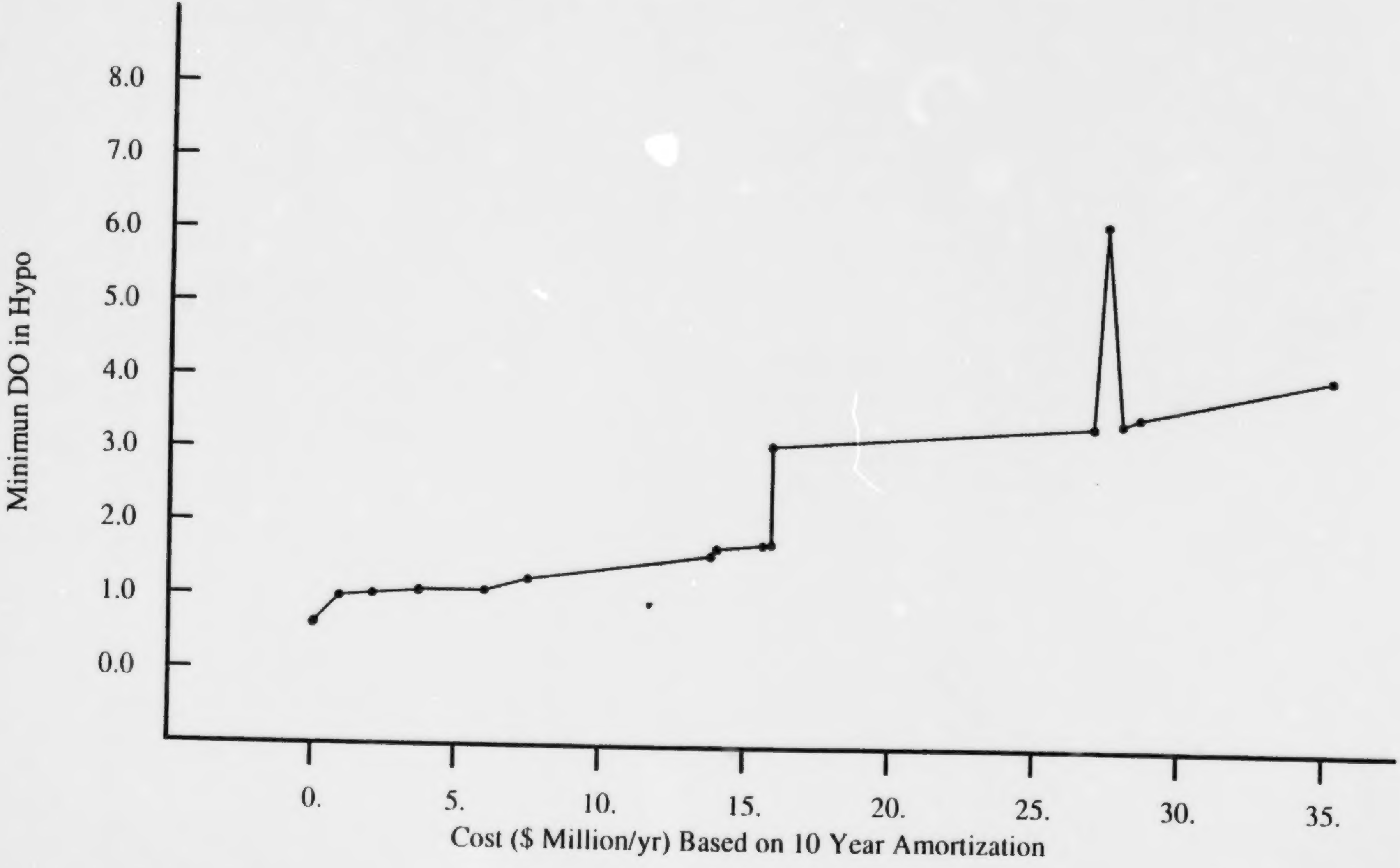


Figure 3.5d. Cost (Log Scale; 20 Year Amortization) of Improving Hypolimnetic DO by Controlling All Sources.

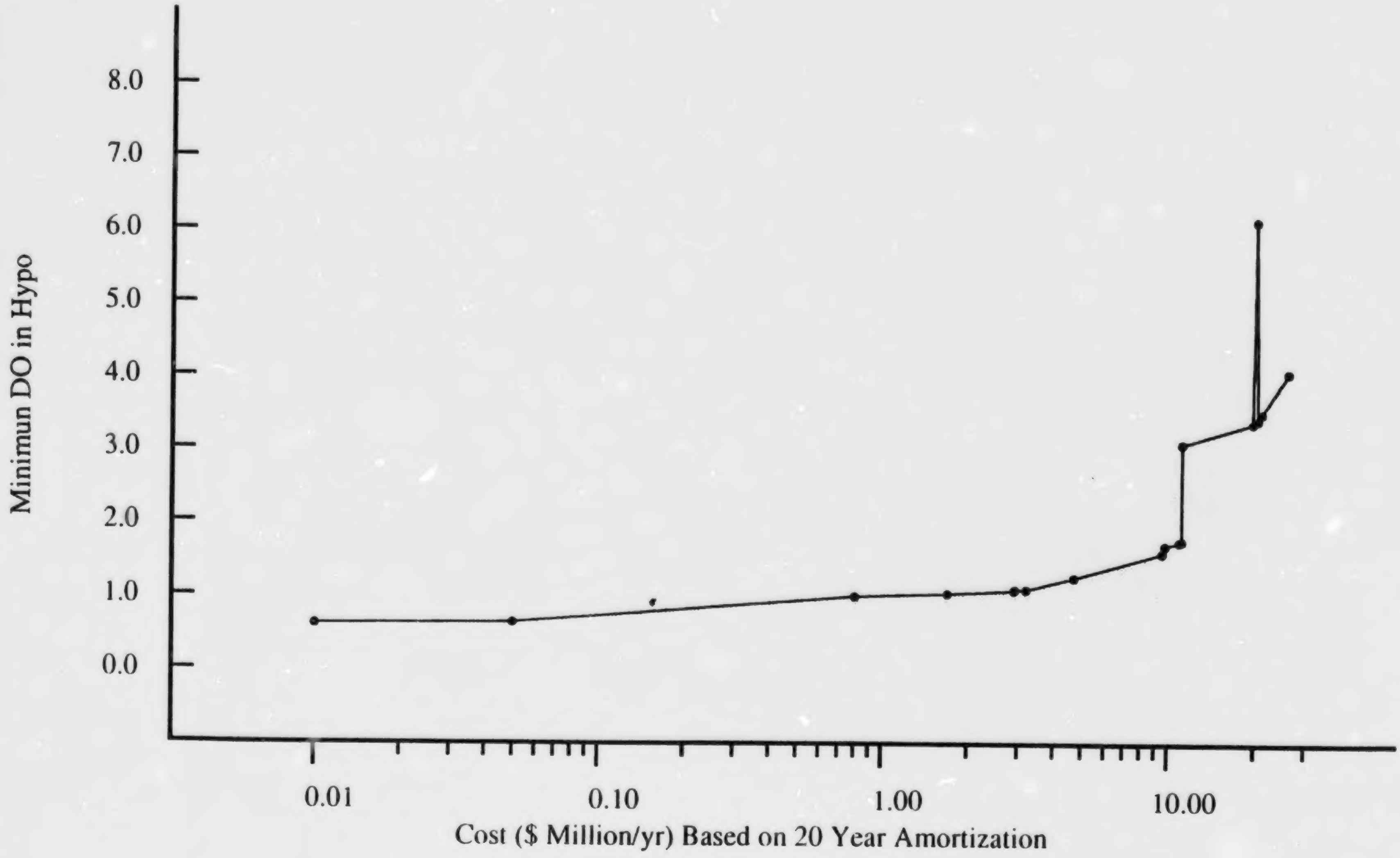
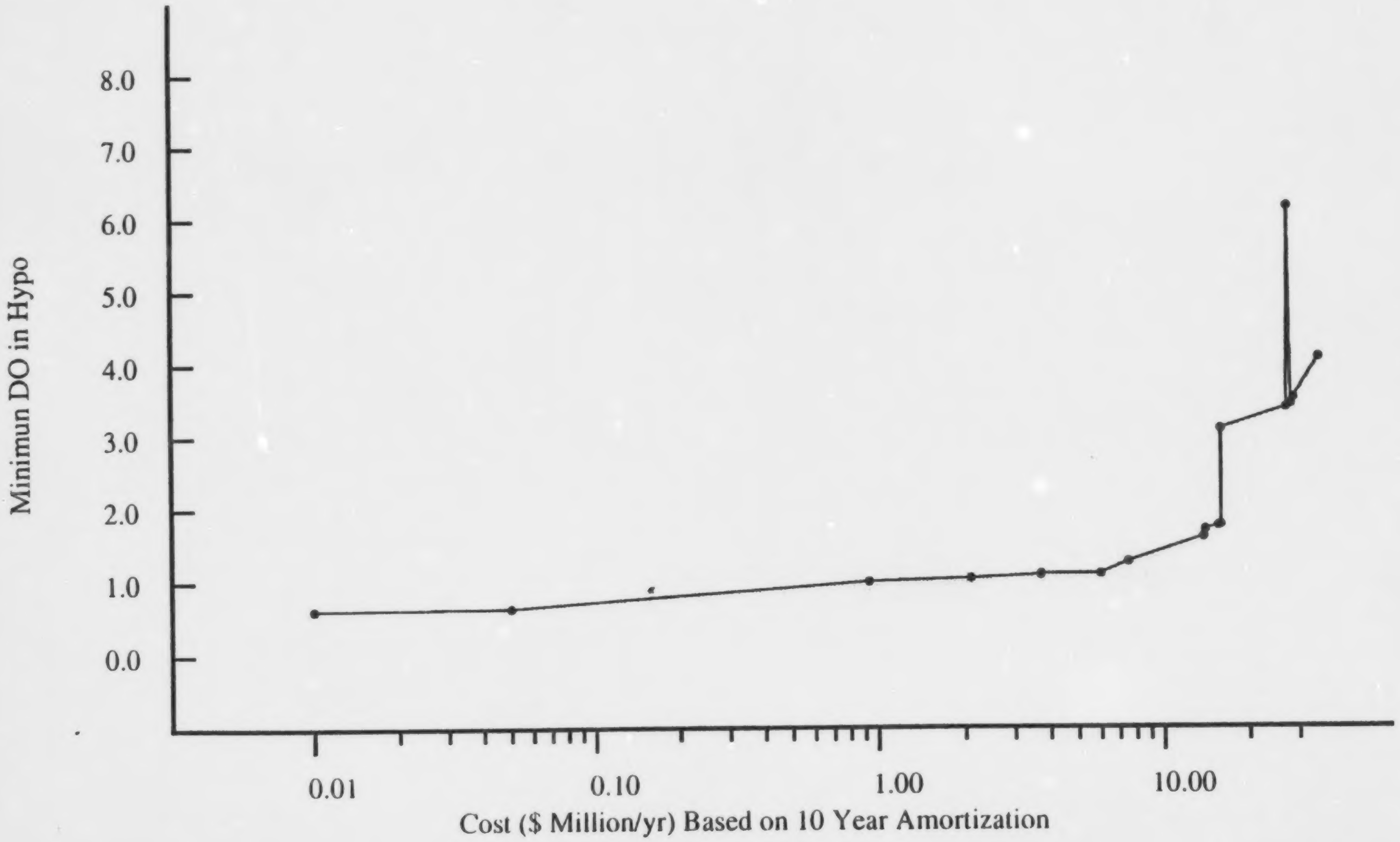


Figure 3.5e. Cost (Log Scale; 10 Year Amortization) of Improving Hypolimnetic DO by Controlling All Sources.



Control of All Sources (Hamilton, Burlington, Industrial, Diffuse) is required to achieve a marked improvement (see Figure 3.5a) in dissolved oxygen, but a noticeable improvement should result for only control of Hamilton Sources (Figure 3.2a).

Additional chemical precipitation at the Hamilton Sewage Treatment Plant (Control 2, Figure 3.5a) in which the average total phosphorus concentration in the effluent decreases to 0.7 mg/L does not influence the calculated minimum DO_h. But, with nitrification of 90% of the current load from the Hamilton Sewage Treatment Plant in addition to control of phosphorus (0.7 mg/L TP), there is a small improvement in DO_h (Control 3 , Figure 3.5a). Nitrification at the Burlington SewageTreatment Plant and additional remedial works in the Industrial sector do not have a marked effect upon DO_h.

Control of agricultural sources of phosphorus (Control Number 8) has a small effect. Implementation of sand filters at Hamilton (Control Number 9) has a noticeable effect upon DO_h; implementation of dual point and sand filters at the Hamilton and Burlington Sewage Treatment Plants (Control Numbers 10, 11, and 12) has a small effect.

Natural control, involving a 50% reduction in sediment oxygen demand (SOD) (Control Number 13, Figure 3.5a) results in a substantial increase in dissolved oxygen. This is caused partly by the sensitivity of the system to SOD, but also to the amount of control of phosphorus and ammonia achieved to this point in the sequence of loadings. If the impact of SOD were, for example, evaluated after control option 8, the calculated effect of SOD would be much less than calculated in Figure 3.5a, given the sequence of calculations used in Figure 3.5a.

Of the last five options, both the implementation of CSO control (Option 14) and discharge (Option 18) to Lake Ontario (after effluent of the Hamilton Sewage Treatment Plant and the Burlington Sewage Treatment Plant have a noticeable effect on DO_h; while the Dundas Sewage Treatment Plant and dredging Cootes have only a small effect. Oxygen injection (Option 15) has a very substantial effect.

The routing of the STP discharges from Hamilton Harbour to Lake Ontario has a small impact because most of the nutrient levels currently discharged by the STP's are removed by the control measures previously evaluated in the control sequence.

Changes in the cost-effectiveness curves for Control of all sources (Figure 3.5b to e) are gradual, except for the large cost increments associated with implementations of the following strategies:

(i) sand filters;
(ii) treatment of Combined Sewer Overflow's; and
(iii) discharge to Lake Ontario.

The implementation of sand filters (Option 9), CSO (Control Option 14) and discharge to Lake Ontario (Option 18) are calculated to cause a small but noticeable amount of improvement in DO_h, for a large amount of money (approximately $4-6 million per year for implementation of each option). These improvements in DO_h compared to their cost appear to be small compared to the effect of natural control and oxygenation; however, this comparison is not fair strictly upon a control basis. Natural control is only possible after reduction in nutrient loadings and requires Options 1-11 before most of its effect would be realized. Oxygenation is a technique which would require continual implementation each summer; its effect would be mainly upon oxygen.

3.4.7 - Results: Cost Effectiveness of Restoration of Littoral Fish Habitat

The calculations of cost effectiveness for improvement in Littoral Fish Habitat due to remedial measures are give in Figure 3.6 and 3.7. The sequence of control options considered in Figure 3.6 are the same sequence of options as considered in Figure 3.2 for control of Hamilton sources; the sequence of control options in Figure 3.7 are the same sequence as remedial and mitigating measures for all sources as considered in Figure 3.5 for DO. The calculations are given in the figures as follows:

3.6a	Change in Percent of Macrophyte Habitat as a Function of Controlling Hamilton Sources.
3.6b	Cost (Log Scale; 20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.
3.6c	Cost (Log Scale; 10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.
3.6d	Cost (20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.
3.6e	Cost (10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.

3.7a Change in Percent of Macrophyte Habitat as a Function of Controlling all Sources.

3.7b Cost (Log Scale; 20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling All Sources.

3.7c Cost (Log Scale; 10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling All Sources.

3.7d Cost (20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling All Sources.

3.7e Cost (10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling All Sources.

Control of Hamilton sources (Figure 3.6a) results in a small improvement in habitat from the 20-30% range to the 30 to 50% range with every option having a small positive effect. Control of all sources (Figure 3.7a) results in three distinct sections to the cost-effectiveness curve: options 1 to 8; options 9 to 13 and options 14 to 18. The first 8 options represent nitrification of effluents and industrial source control; these options have minimal impact upon phosphorus control. The second section in the curve is caused by the initiation of additional phosphorus control through the implementation of sand filters in Hamilton (Option 9); this control causes algal densities to decrease and the depth of light penetration to increase, allowing for additional littoral habitat. The implementation of dual point injection of Hamilton (Option 10) and sand filters with dual point injection at Burlington (Option 11 and 12) and natural control (Option 13) have a minimal impact relative to the installation of filters at the Hamilton-Wentworth Sewage Treatment Plant (Option 9).

In the third section of the curve, CSO control (Option 14) has a larger effect upon fisheries habitat than the other options. However, the sequence of options 14 (CSO control), 16 (Dundas STP), 17 (Dredging Cootes) and 18 (Discharge to Lake Ontario) has a distinct effect upon littoral habitat.

3.4.8 - Results: Effectiveness for Other Nutrient Parameters

The calculations of the change in water quality in the Harbour for "Water Quality Scenario 4: Control of all Sources" is given for different water quality paramenters in the following figures.

Figure 3.8a Ammonia Concentration in the Epilimnion During Summer for Overall Control

Figure 3.8b Ammonia Concentration in the Hypolimnion During Summer for Overall Control

HAMILTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Sand Filters - HWSTP
5	Dual Point Chemical Addition - HWSTP
6	Retention Basins
7	Discharge to Lake Ontario

HAMILTON SEWAGE TREATMENT PLANT
WASTE EFFLUENT CONTROLS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Sand Filters - HWSTP
5	Dual Point Chemical Addition - HWSTP
6	Retention Basins
7	Discharge to Lake Ontario

Figure 3.6a. Change in Percent of Macrophyte Habitat as a Function of Controlling Hamilton Sources.

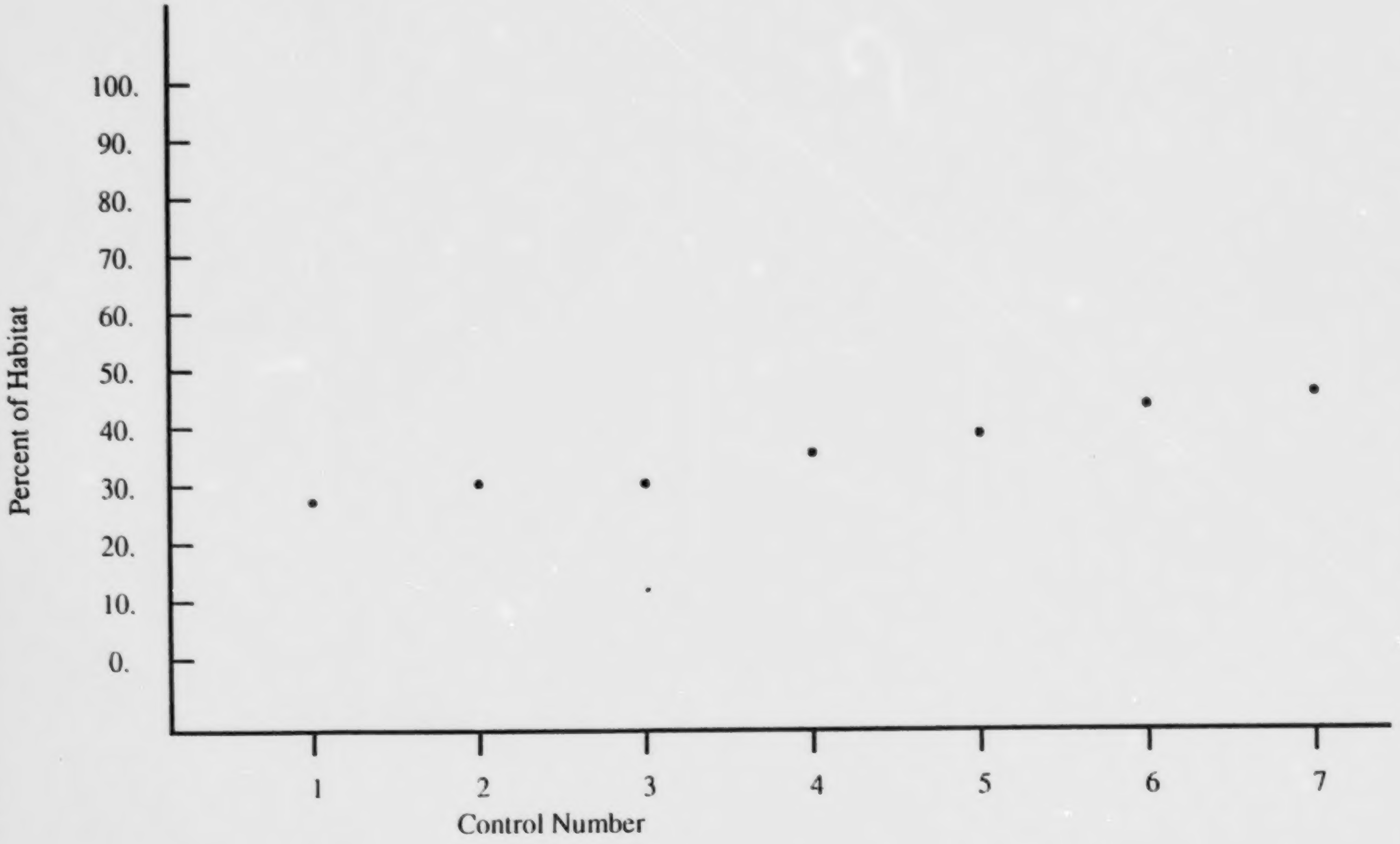


Figure 3.6b. Cost (Log Scale; 20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.

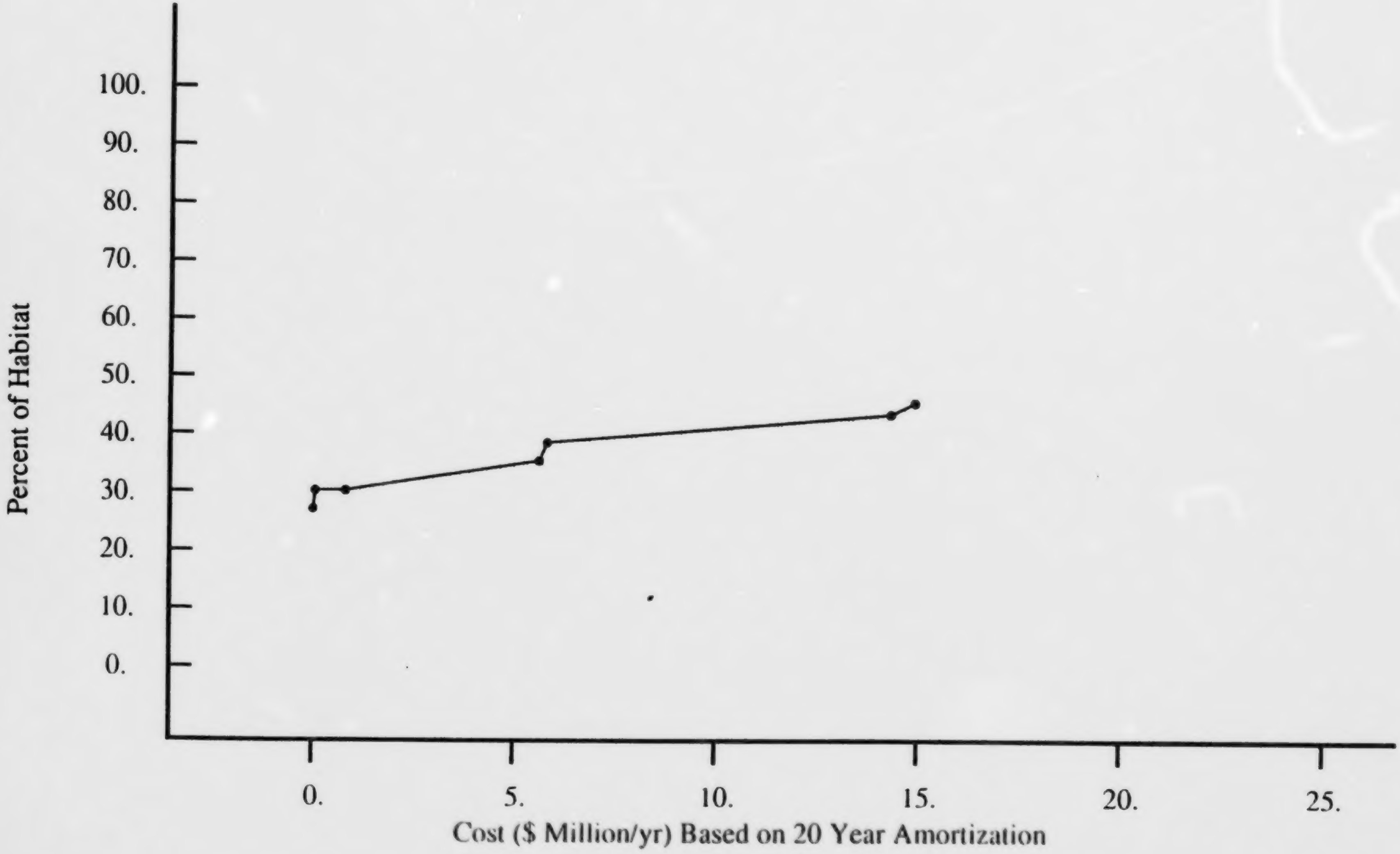


Figure 3.6c. Cost (Log Scale; 10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.

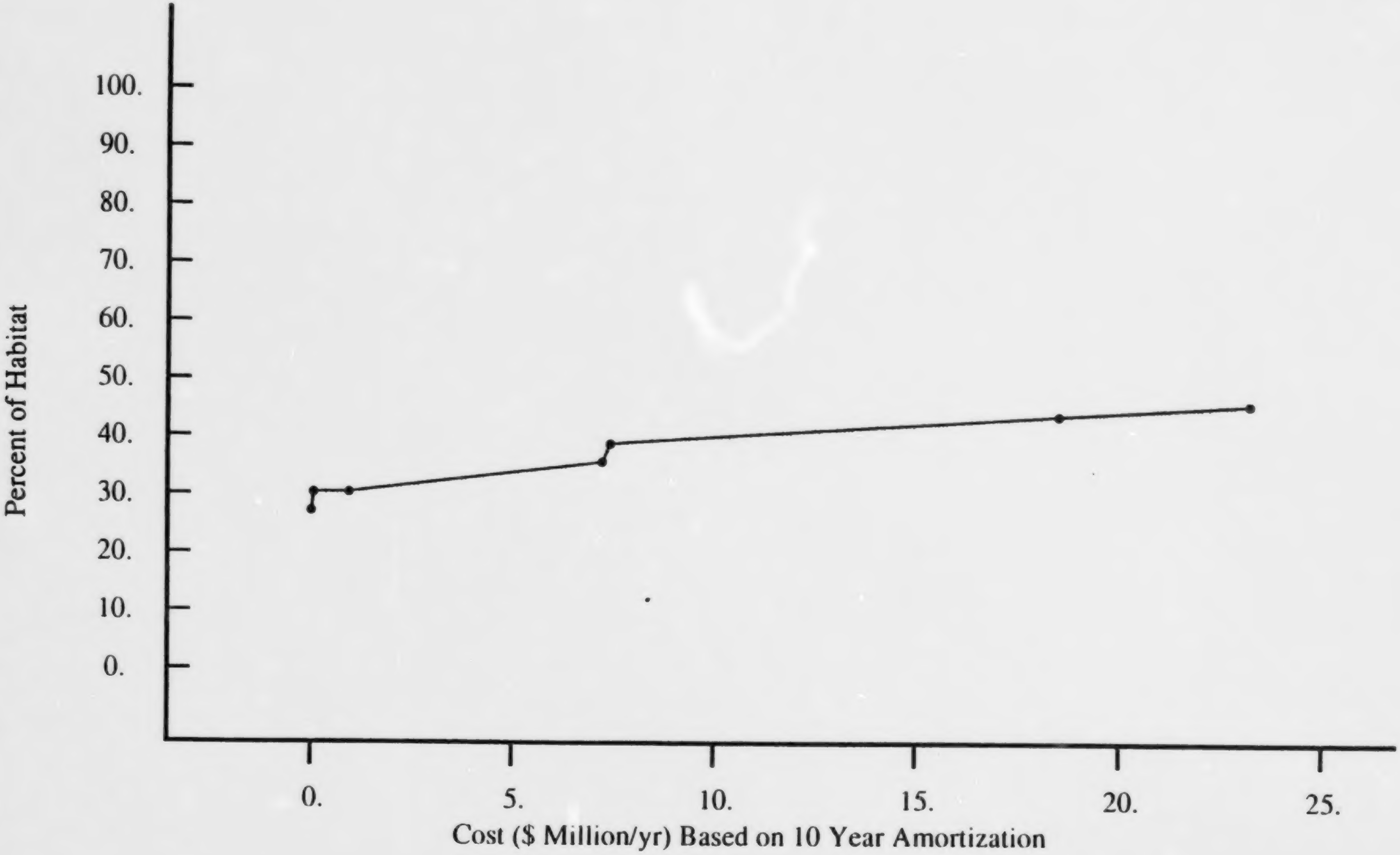


Figure 3.6d. Cost (20 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton, Sources.

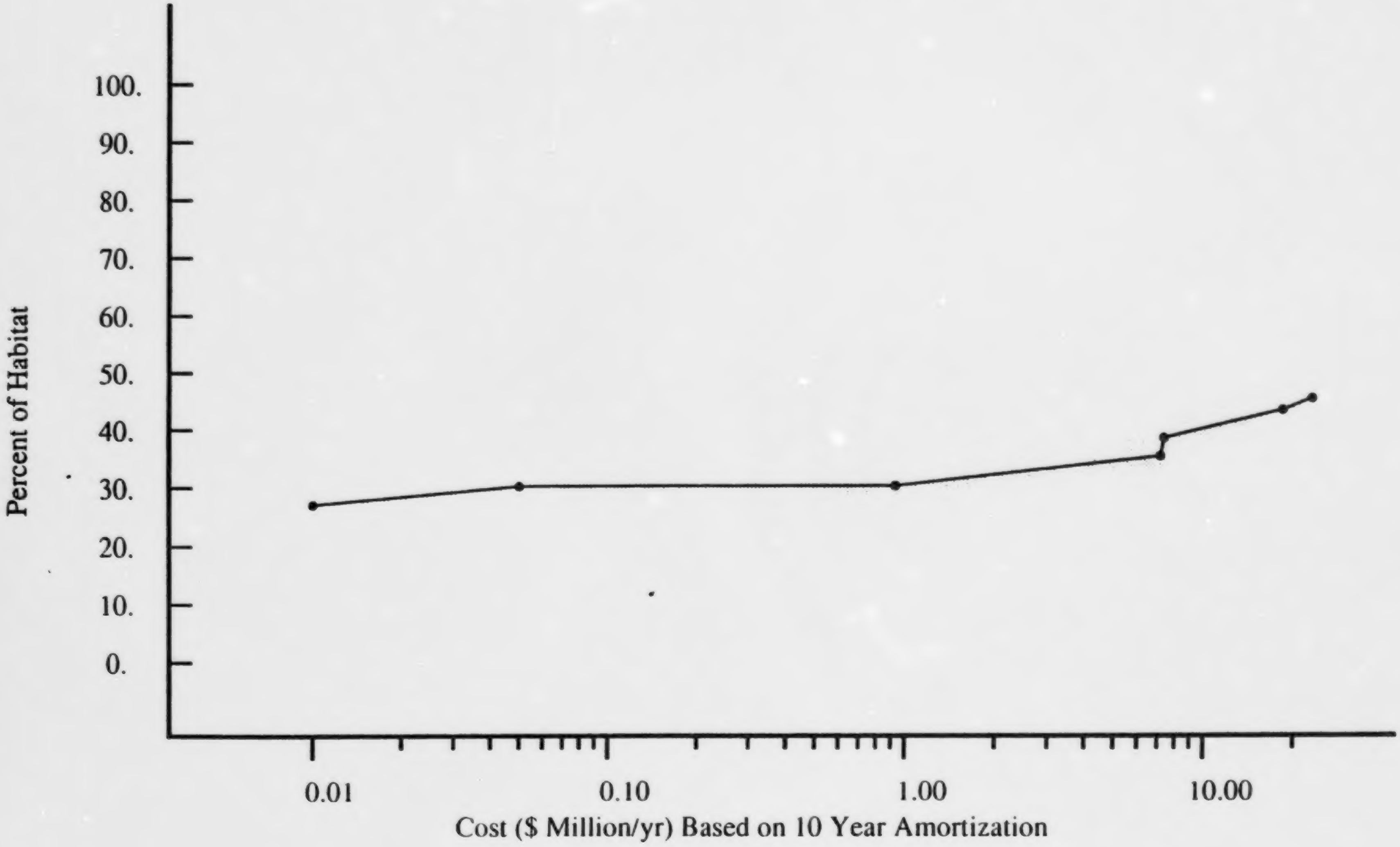
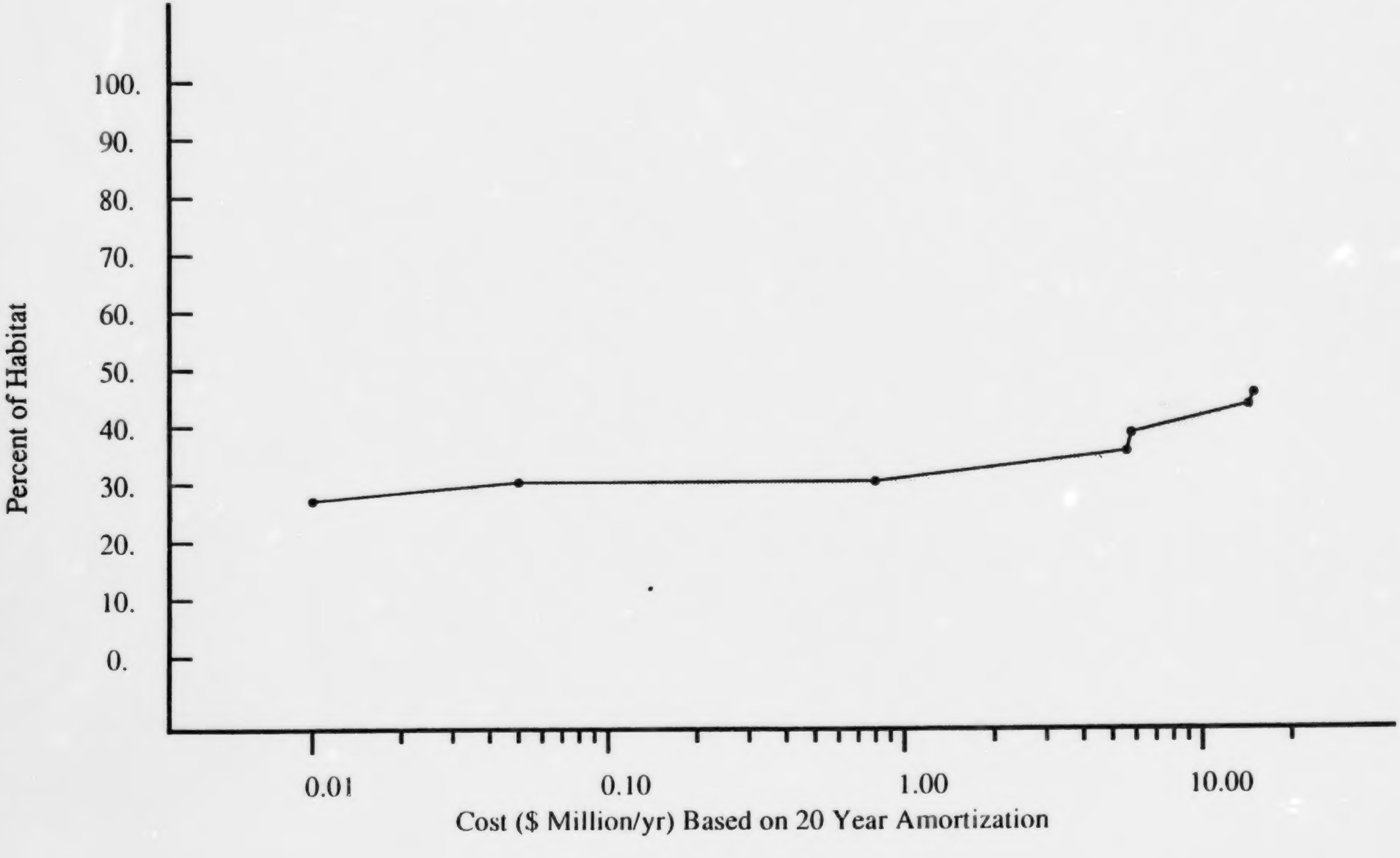


Figure 3.6e. Cost (10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling Hamilton Sources.



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.7a. Change in Percent of Macrophyte Habitat as a Function of Controlling All Sources.

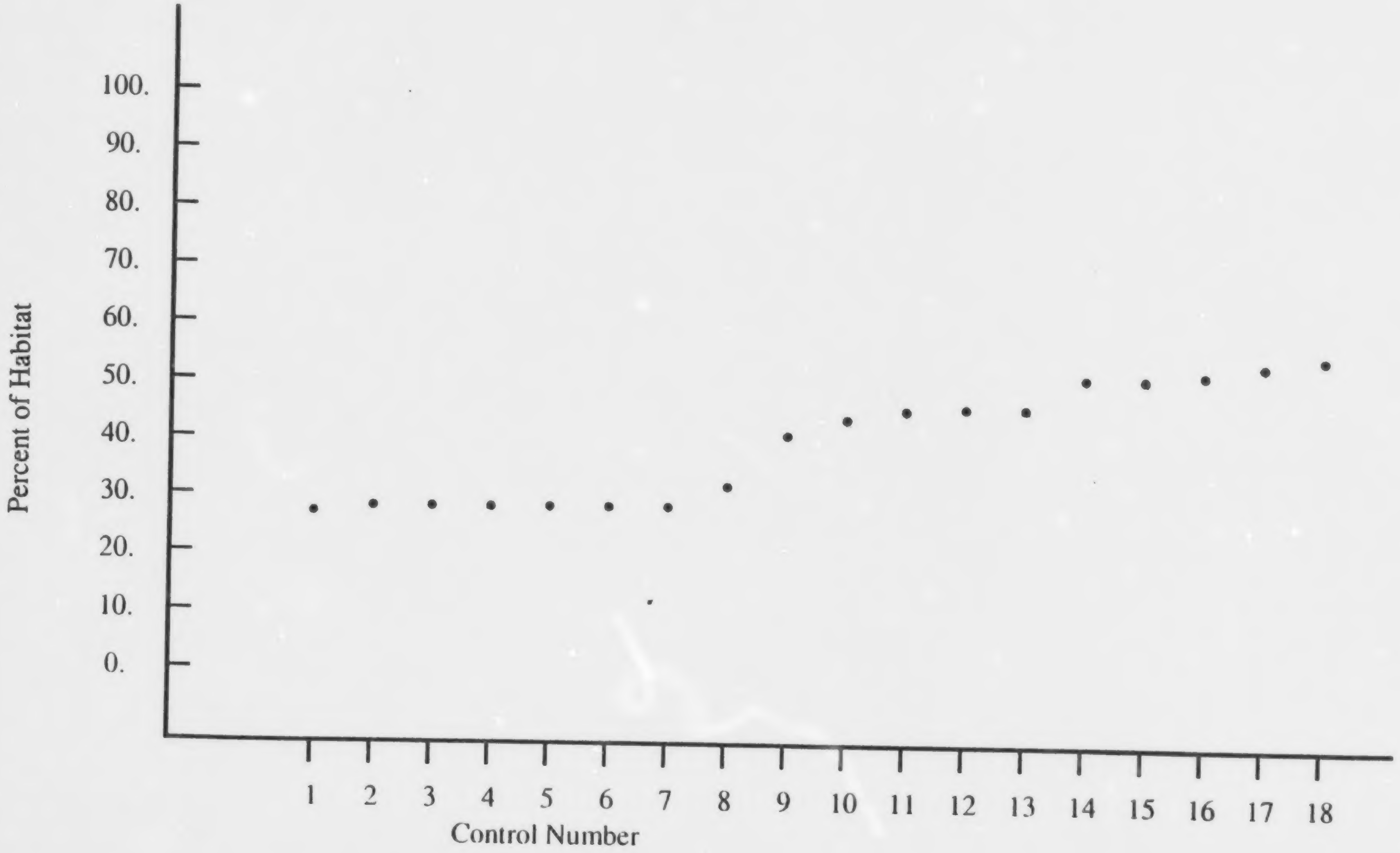


Figure 3.7b. Cost (Log Scale; 20 Year Amortization) of Improving Macrophyte Habitat as a function of Controlling All Sources.

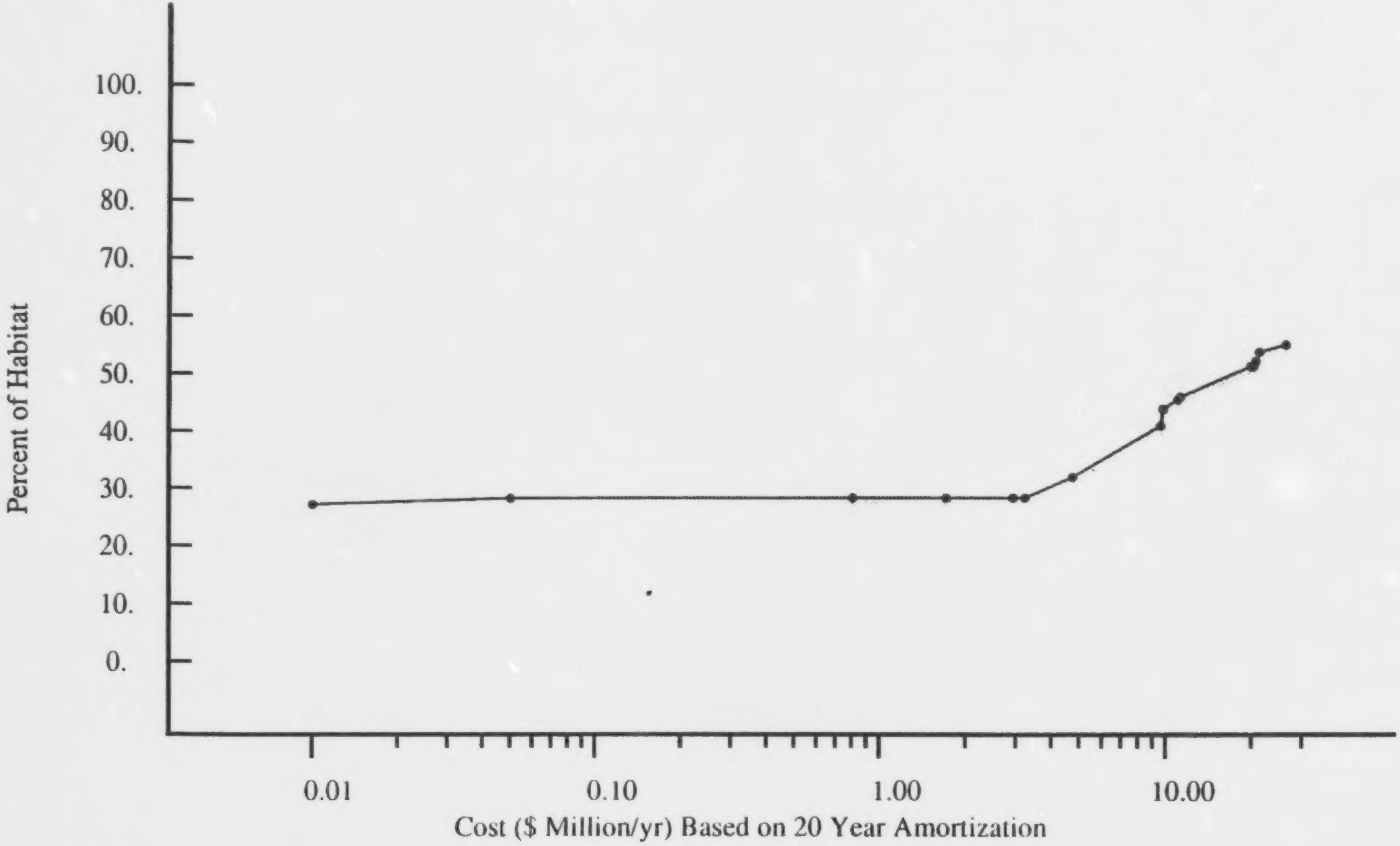


Figure 3.7c. Cost (Log Scale; 10 Year Amortization) of Improving Macrophyte Habitat as a Function of Controlling All Sources.

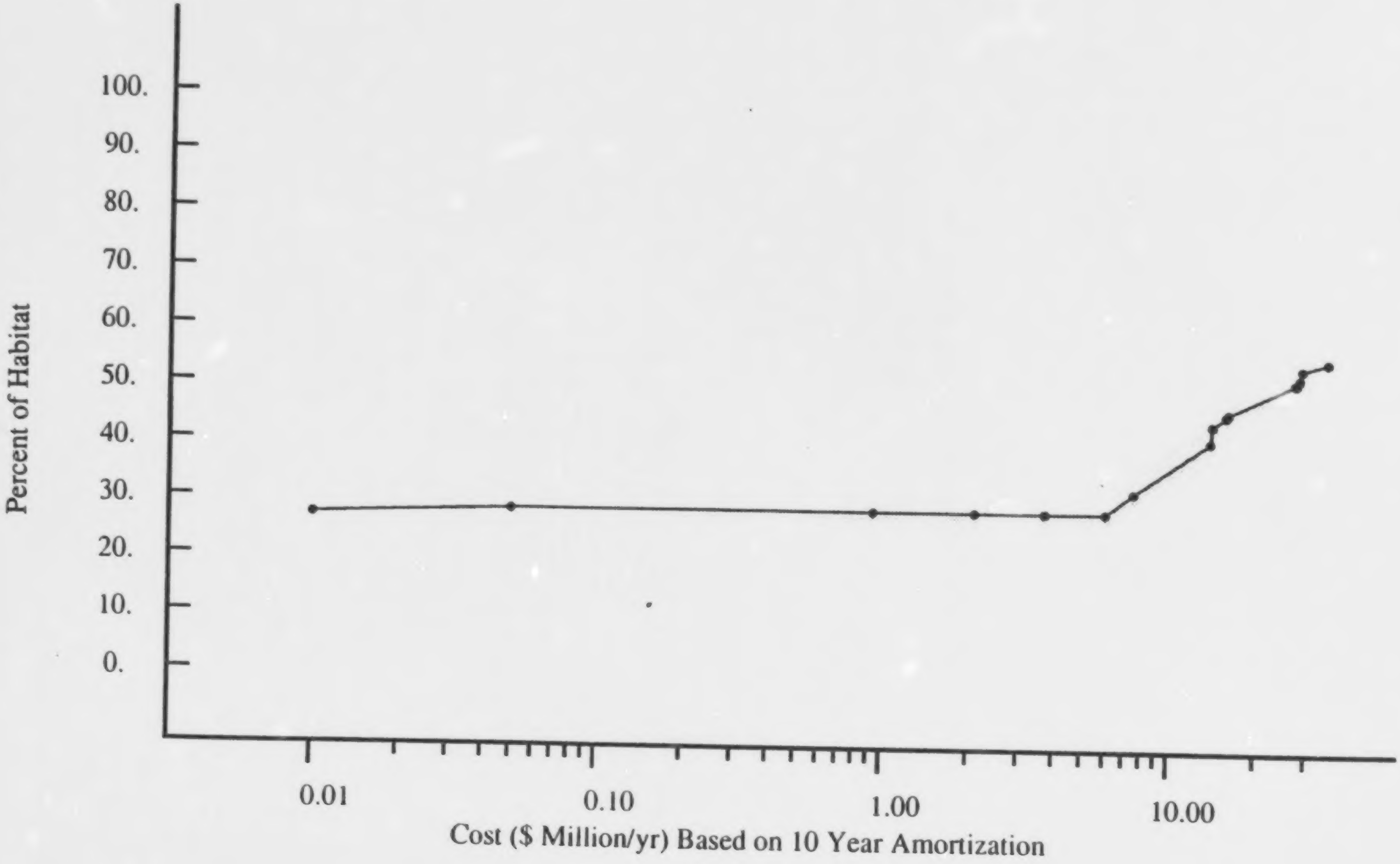


Figure 3.7d. Cost (20 Year Amortization) of Improving Macrophyte Habitat as a function of Controlling All Sources.

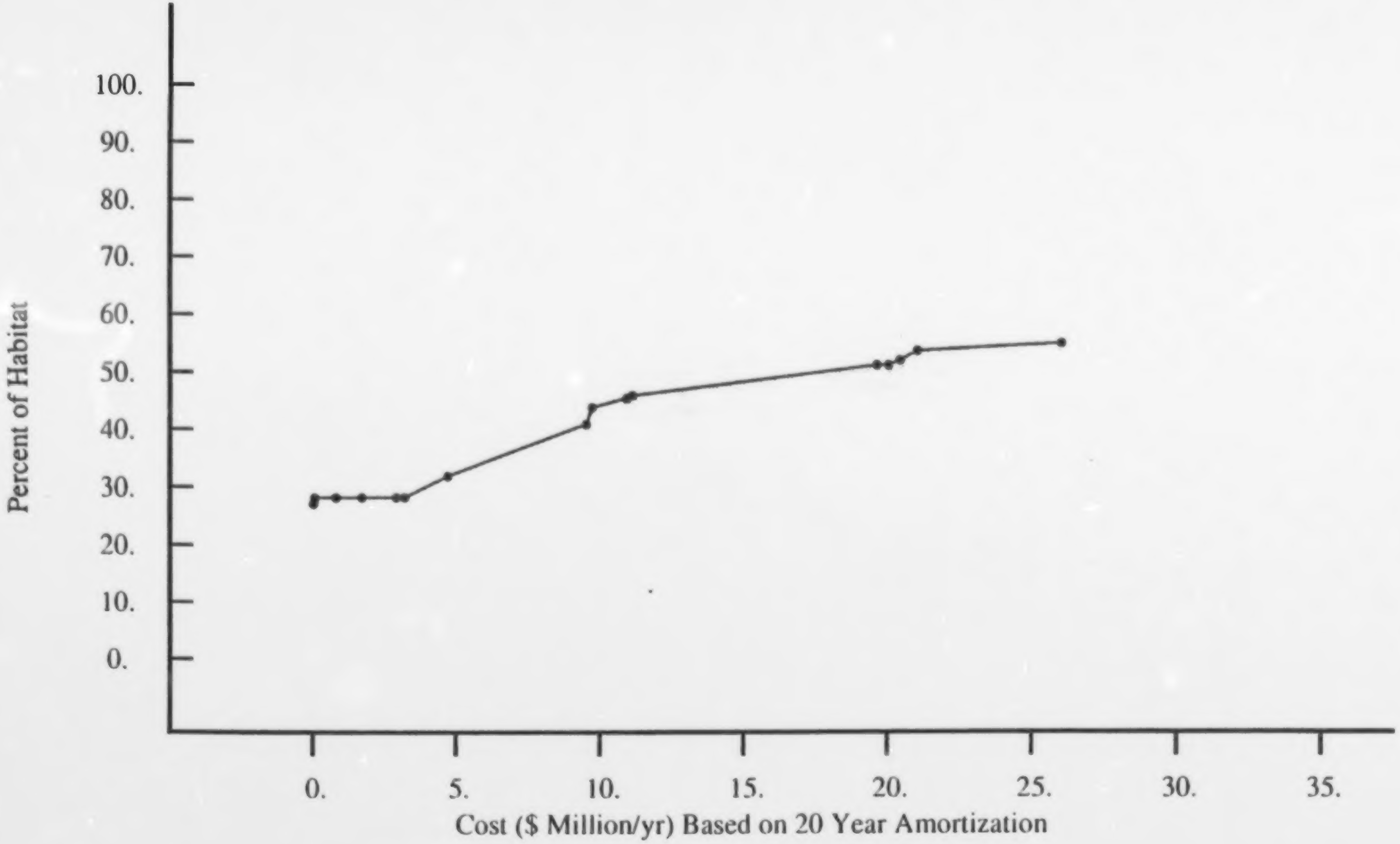


Figure 3.7e. Cost (10 Year Amortization) of Improving Macrophyte Habitat as a function of Controlling All Sources.

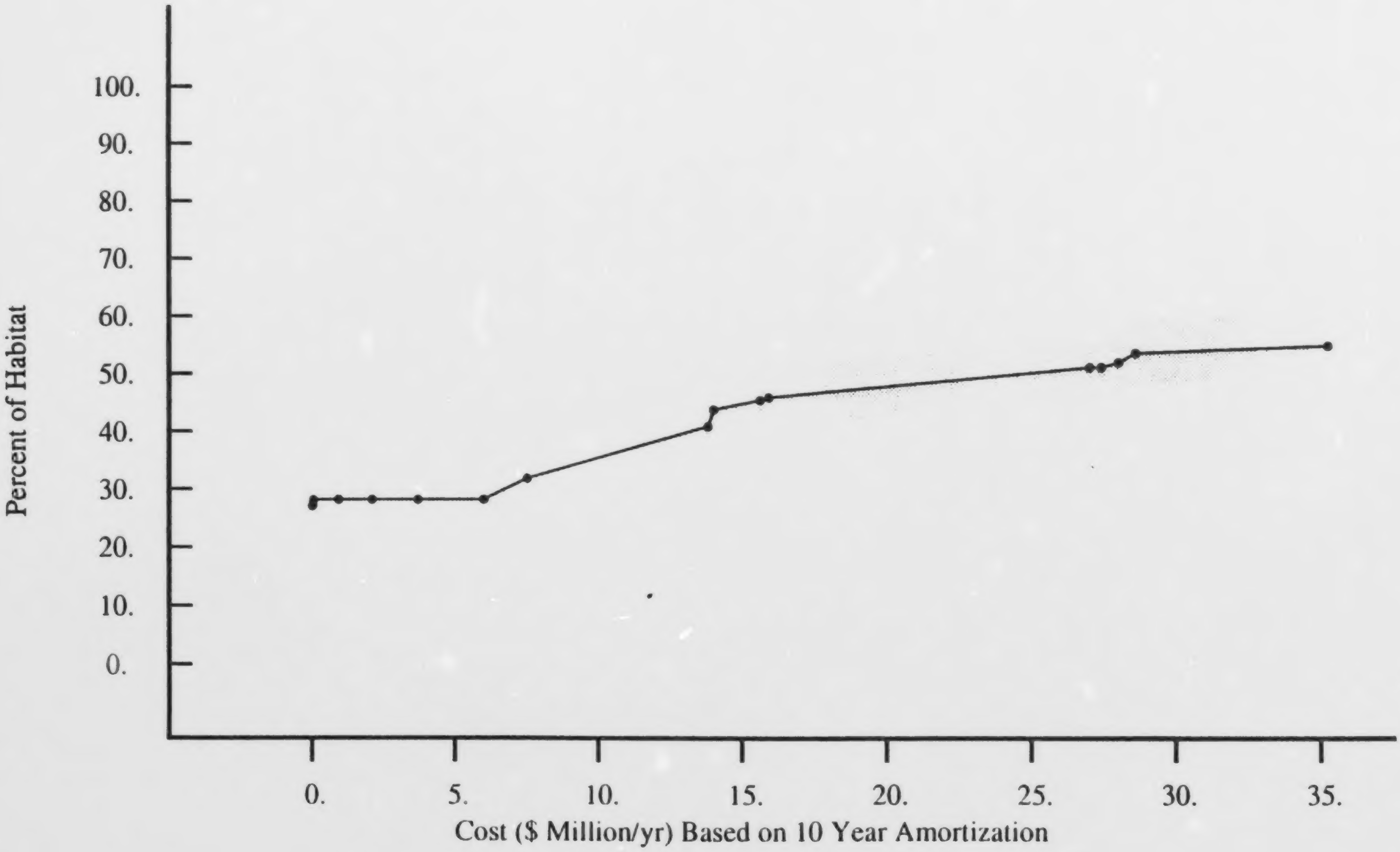


Figure 3.8c	Nitrate Concentration in the Epilimnion During Summer for Overall Control
Figure 3.8d	Nitrate Concentration in the Hypolimnion During Summer for Overall Control
Figure 3.8e	Organic Nitrogen Concentration in the Epilimnion During Summer for Overall Control
Figure 3.8f	Organic Nitrogen Concentration in the Hypolimnion During Summer for Overall Control
Figure 3.8g	Soluable Phosphorus Concentration in the Epilimnion During Summer for Overall Control
Figure 3.8h	Soluable Phosphorus Concentration in the Hypolimnion During Summer for Overall Control
Figure 3.8i	Total Phosphorus Concentration in the Epilimnion During Summer for Overall Control
Figure 3.8j	Total Phosphorus Concentration in the Hypolimnion During Summer for Overall Control
Figure 3.8k	Chlorophyll Concentration in the Epilimnion During Summer for Overall Control
Figure 3.8l	Chlorophyll Concentration in the Hypolimnion During Summer for Overall Control
Figure 3.8m	Extinction Coefficient in the Epilimnion During Summer for Overall Control

The sequence of control Options (1 to 18) as presented in Figure 3.8 as was used for minimum hypolimnetic DO (Figure 3.5a) and Percent Available Fish Habitat (Figure 3.7a). The maximum concentration during the summer months (July and August) for the different water quality paramenters are used in the calculations except for a few parameters for which the maximum August concentration is evaluated.

The eplimnetic chlorophyll and extinction coefficients were used to evaluate the Percent Available Fish Habitat presented in Figure 3.7a.

The ammonia concentrations show a substantial decrease in concentration after implementation of control Option 1 (Hamilton Source Control, Table 3.11) while nitrate shows an increase. This results from conversion of ammonia to nitrate in the wastewater treatment plant. Small changes are also calculated for ammonia and nitrate after Options 4 (Nitrification Burlington Wastewater Treatment Plant) 5, 6, and 7 (Industrial Source Control), 14 (CSO Control) and 18 (Discharge to Lake Ontario). The phosphorus concentrations show a small decreae after Option 2 (chemical precipitation), a larger decreases after Option 9 (sand filters at Hamilton Wastewater Treatment Plant), a set of small decreases with Options 10 to 12 (sand filters and dual

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

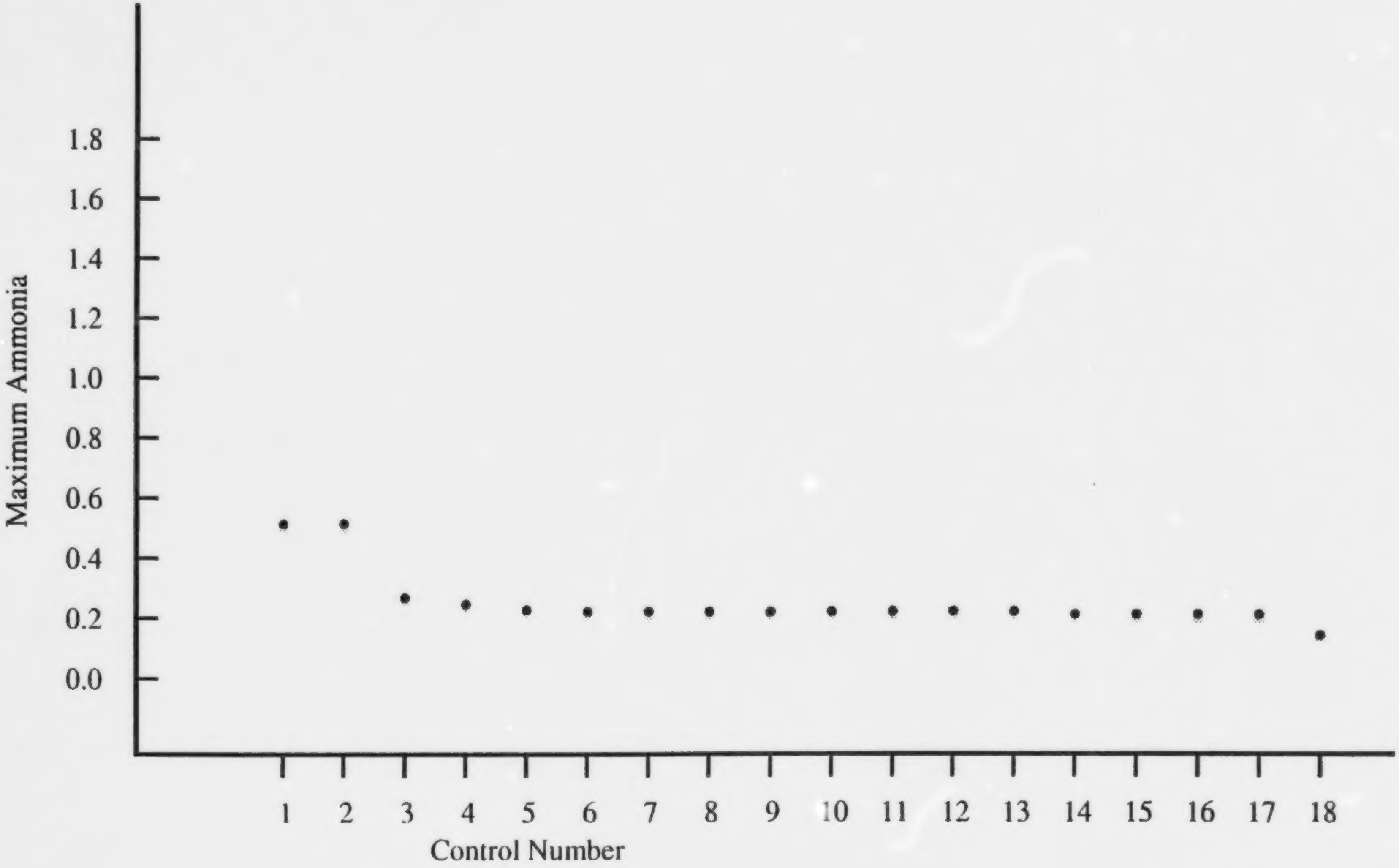
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8a
Ammonia Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

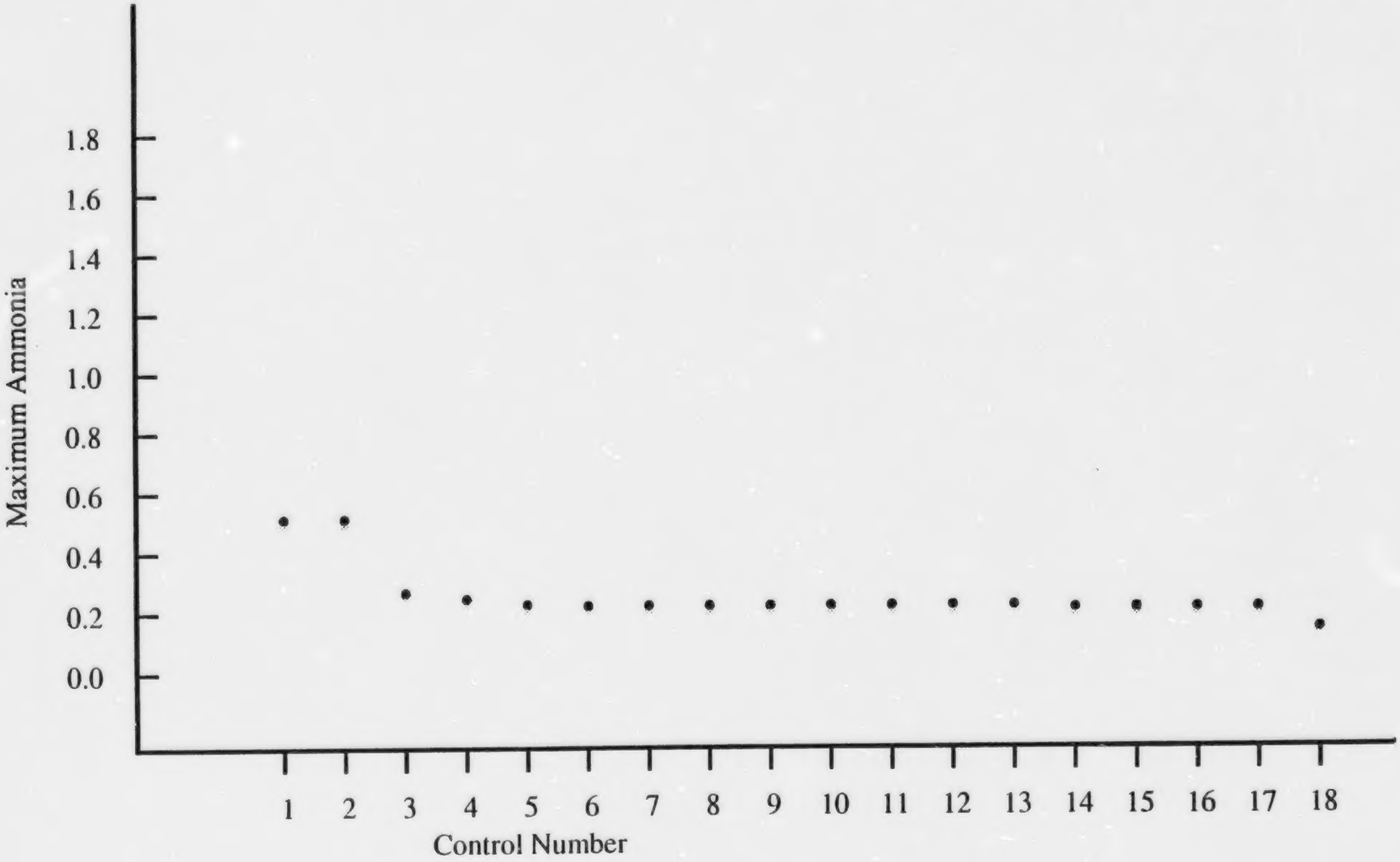
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8b
Ammonia Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

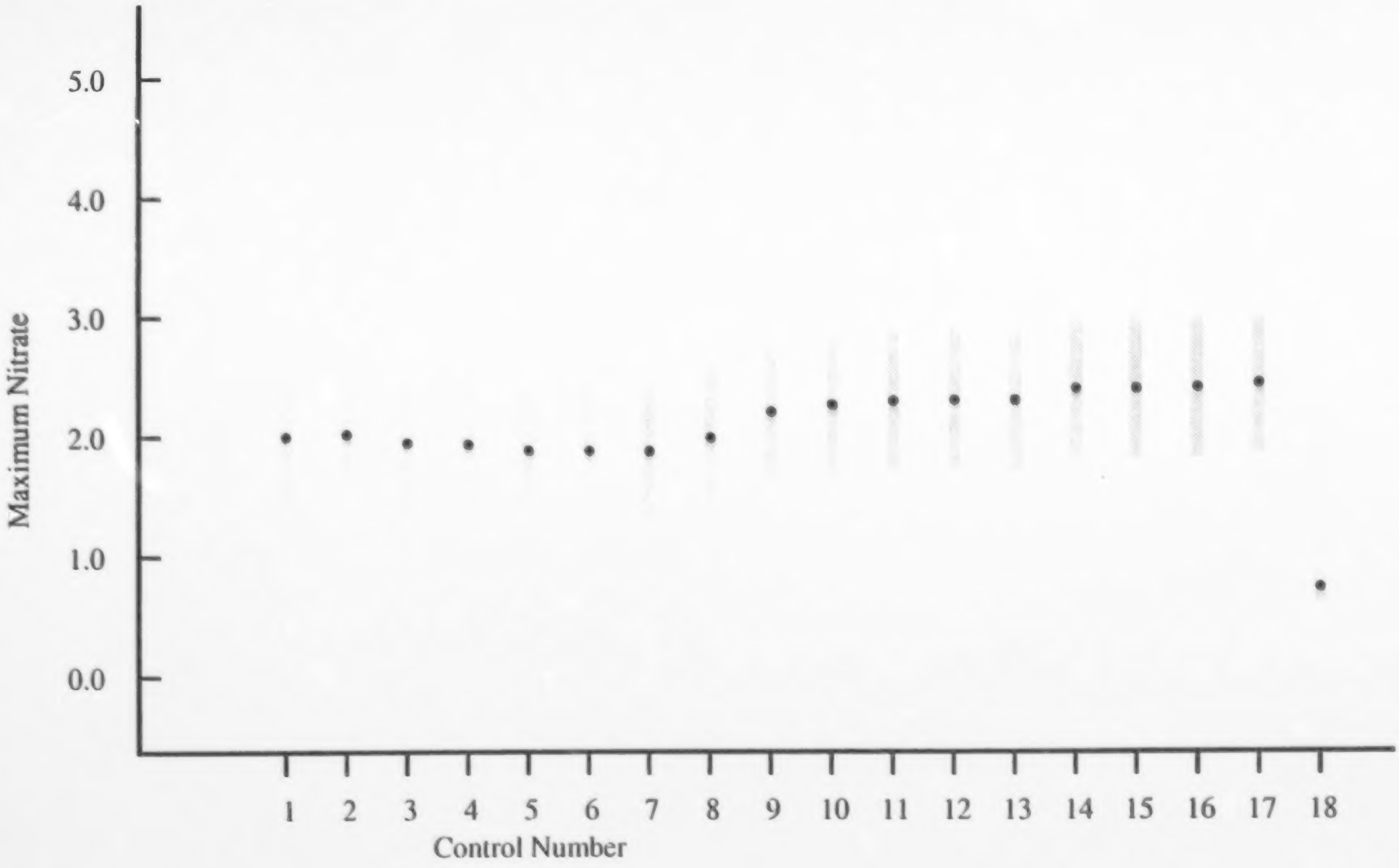
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8c
Nitrate Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

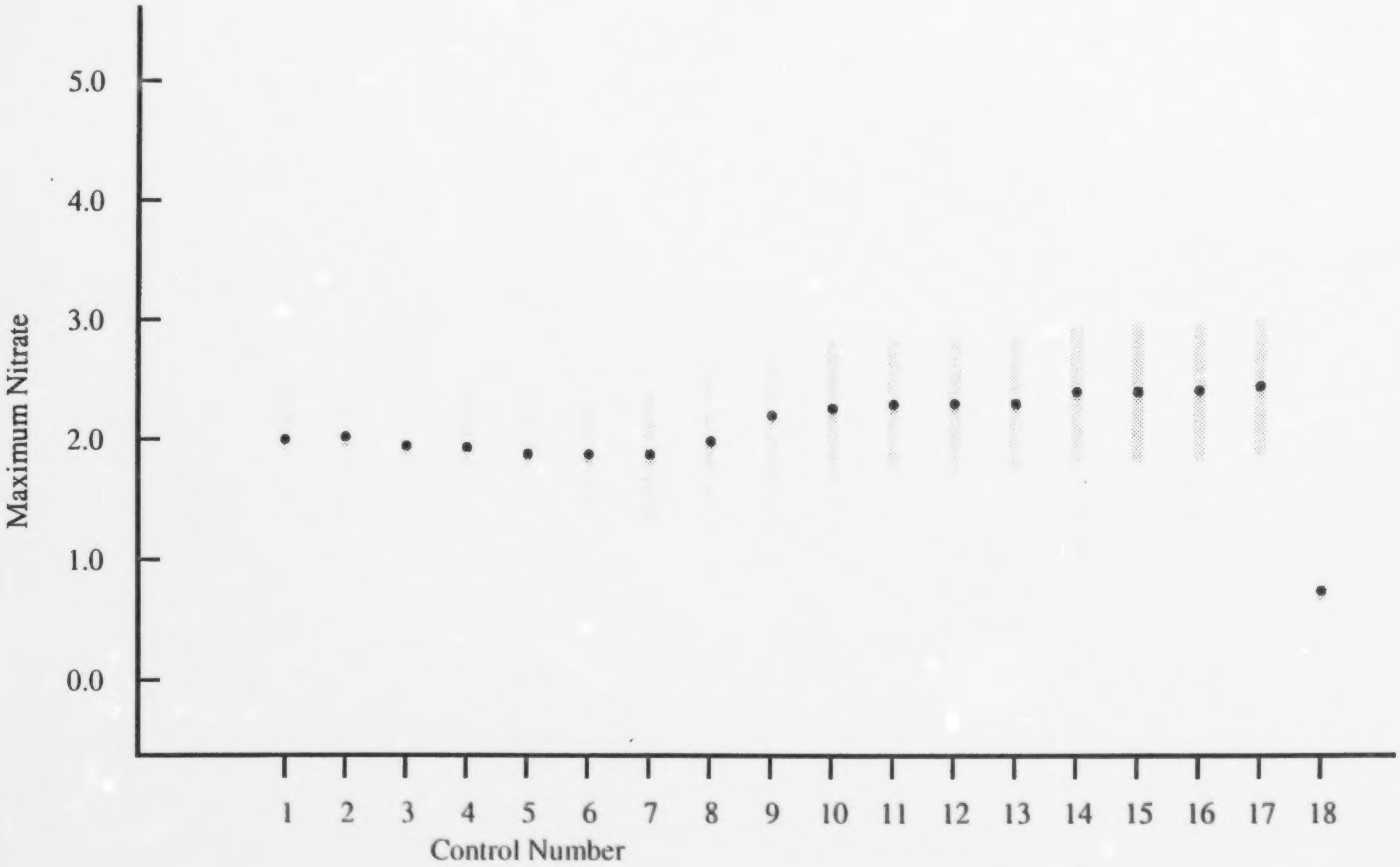
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8d
Nitrate Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

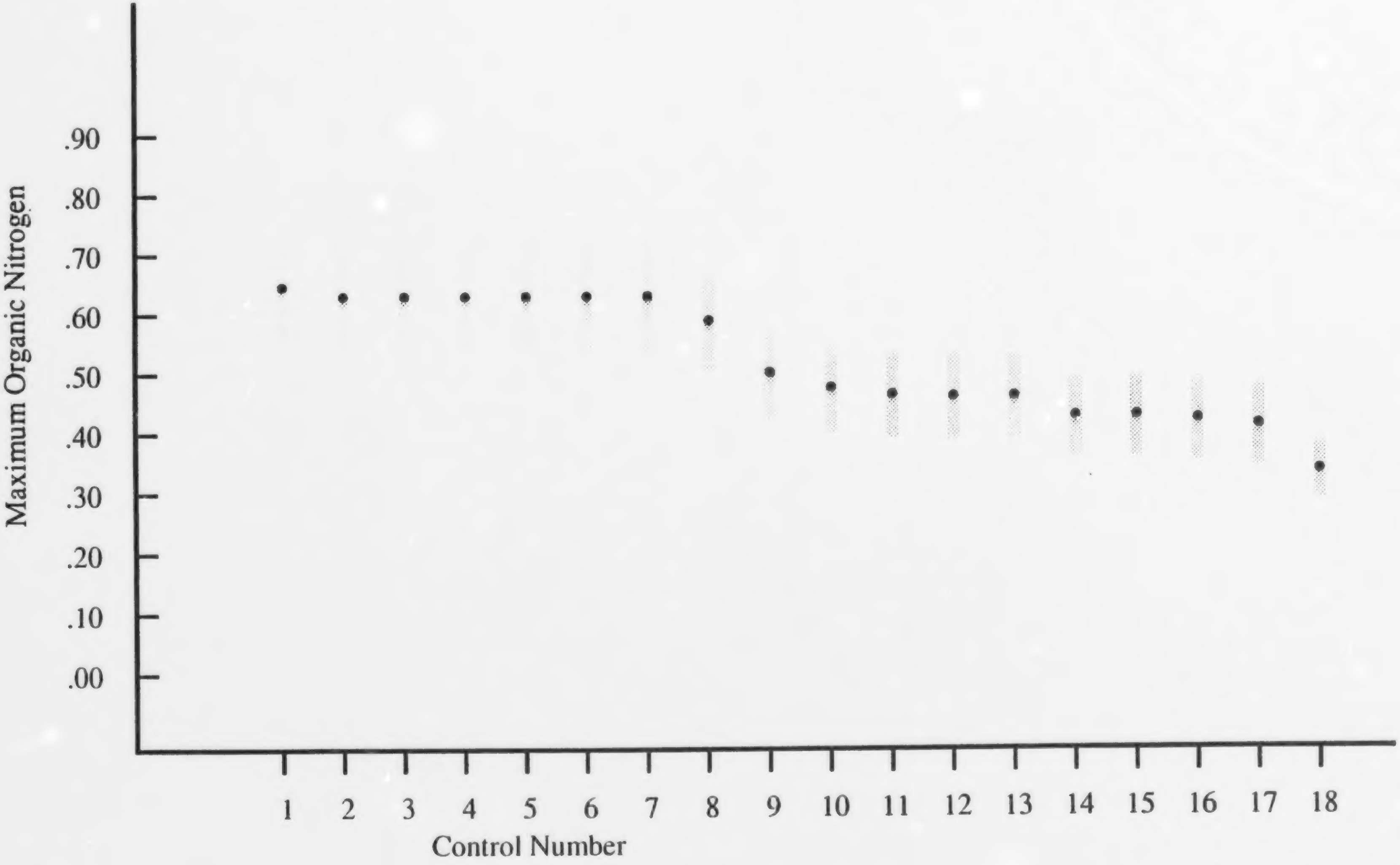
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8e
Organic Nitrogen Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

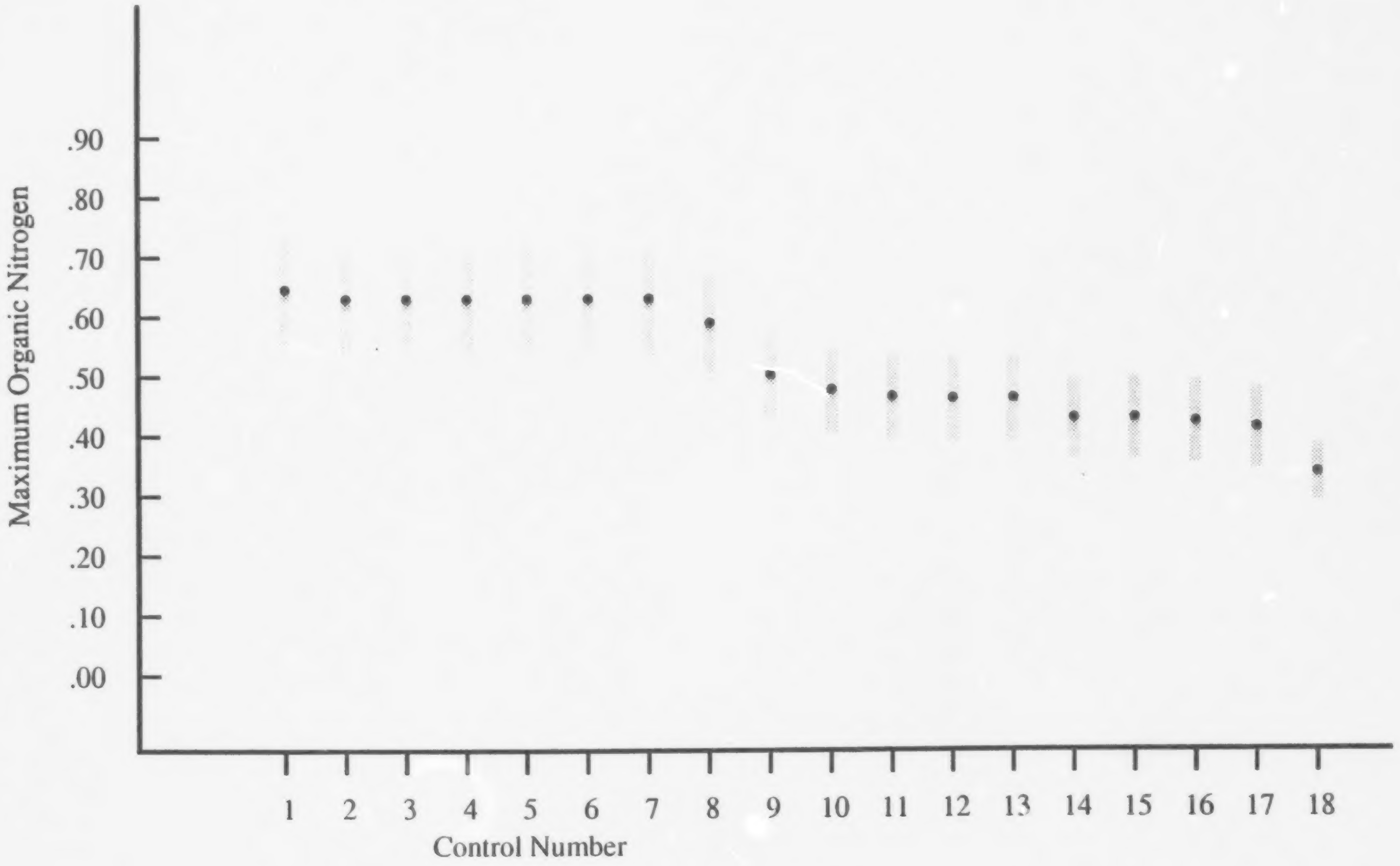
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8f
Organic Nitrogen Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

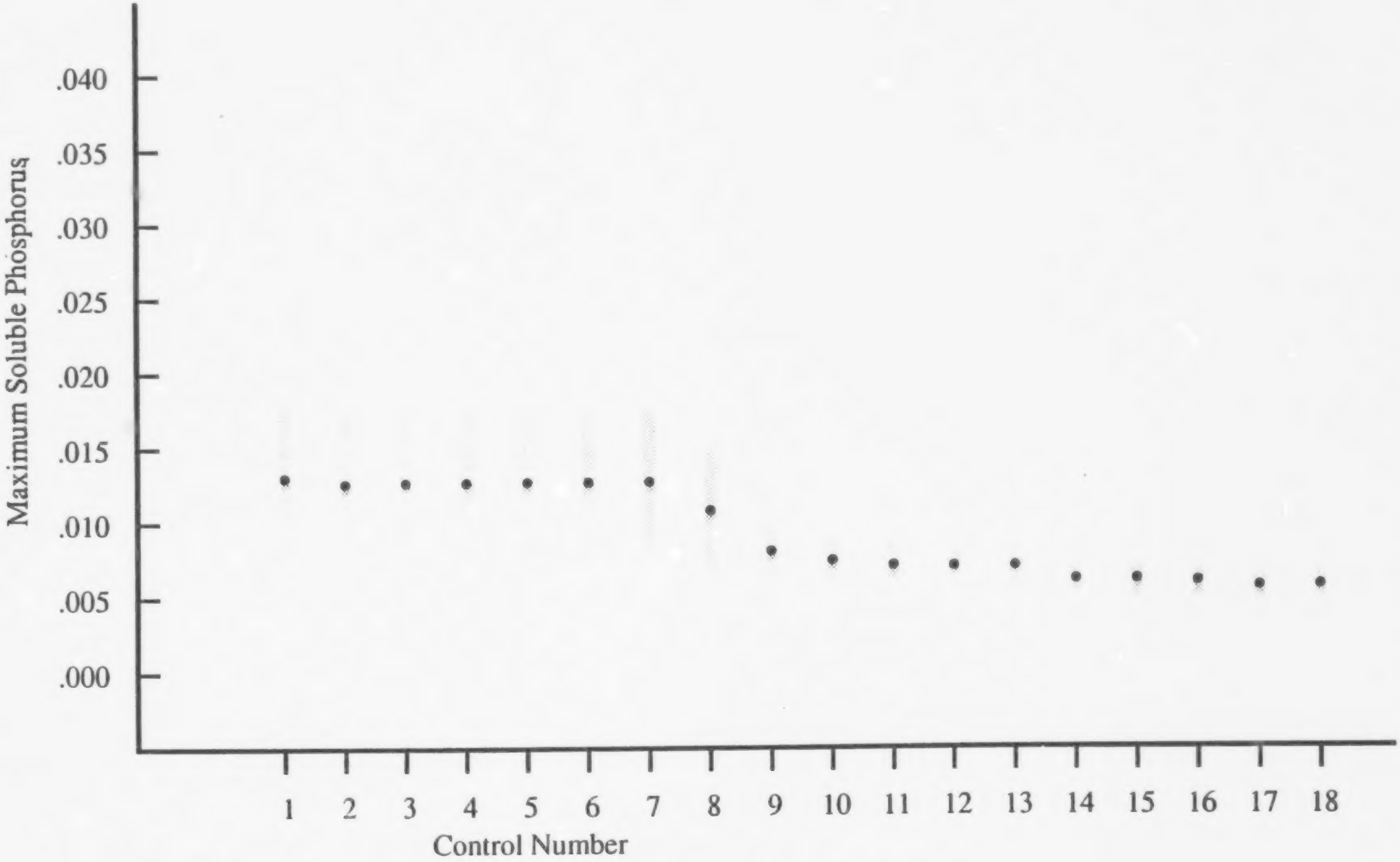
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8g
Soluble Phosphorus Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

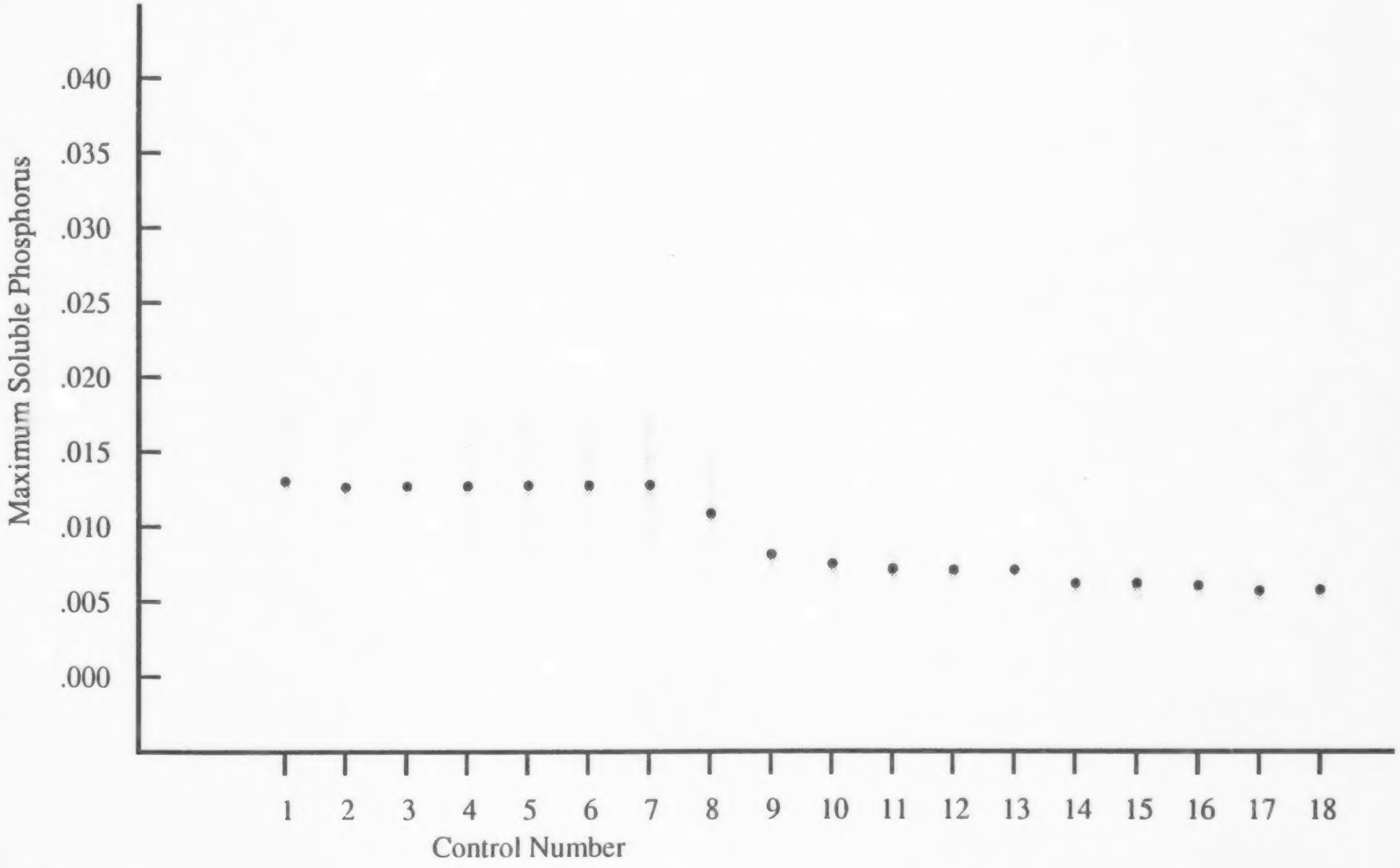
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8h
Soluble Phosphorus Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

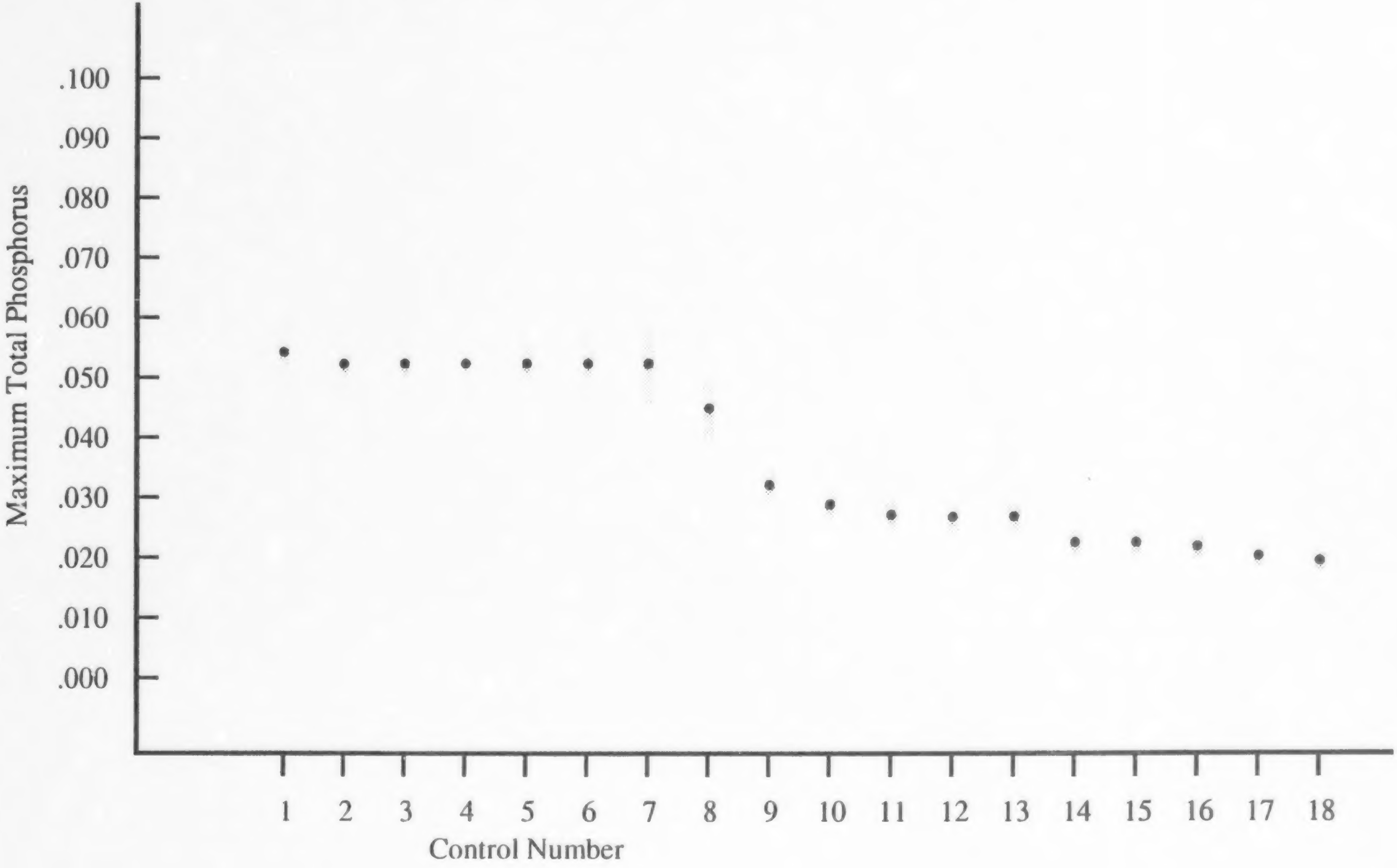
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8i
Total Phosphorus Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

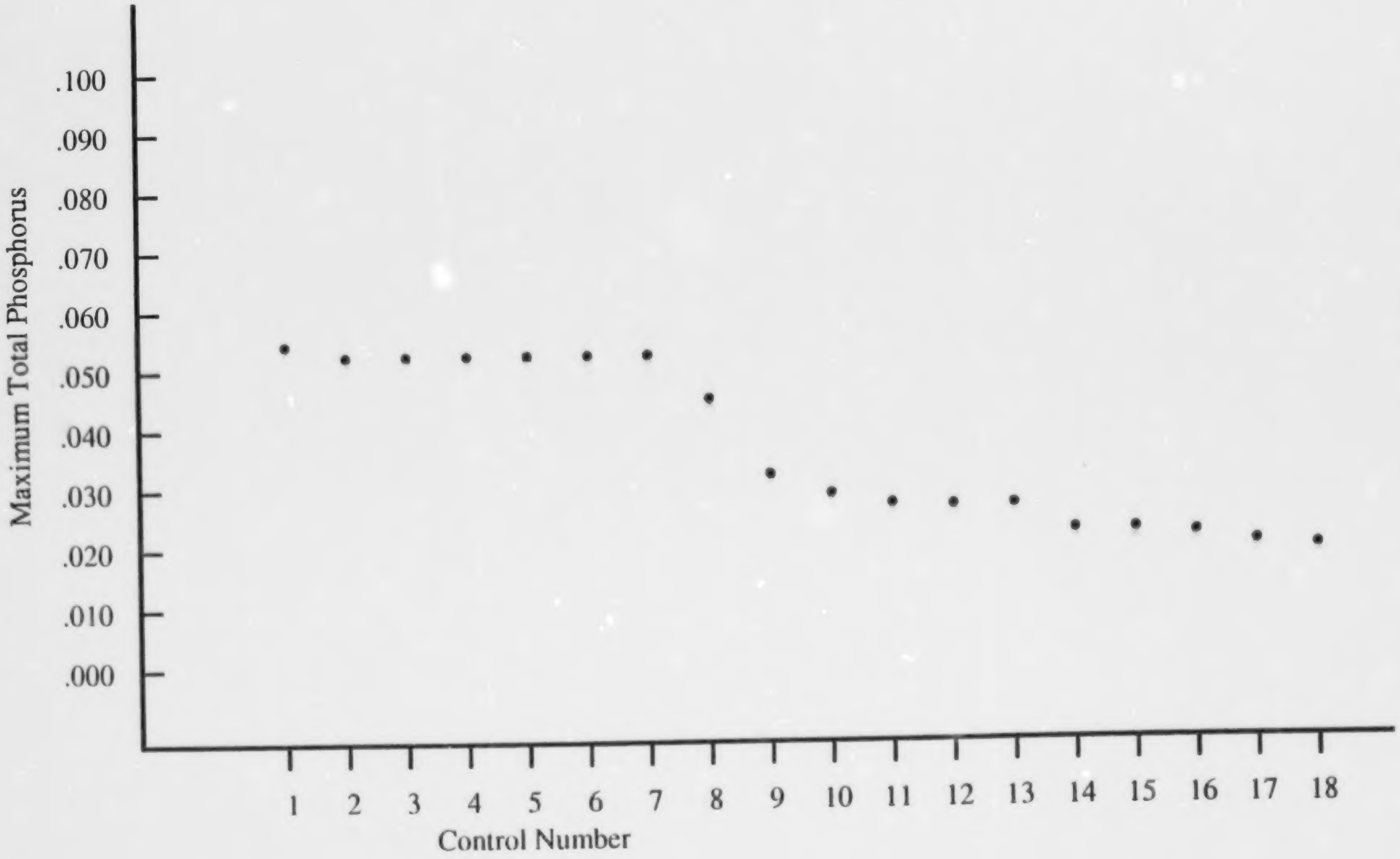
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8j
Total Phosphorus Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

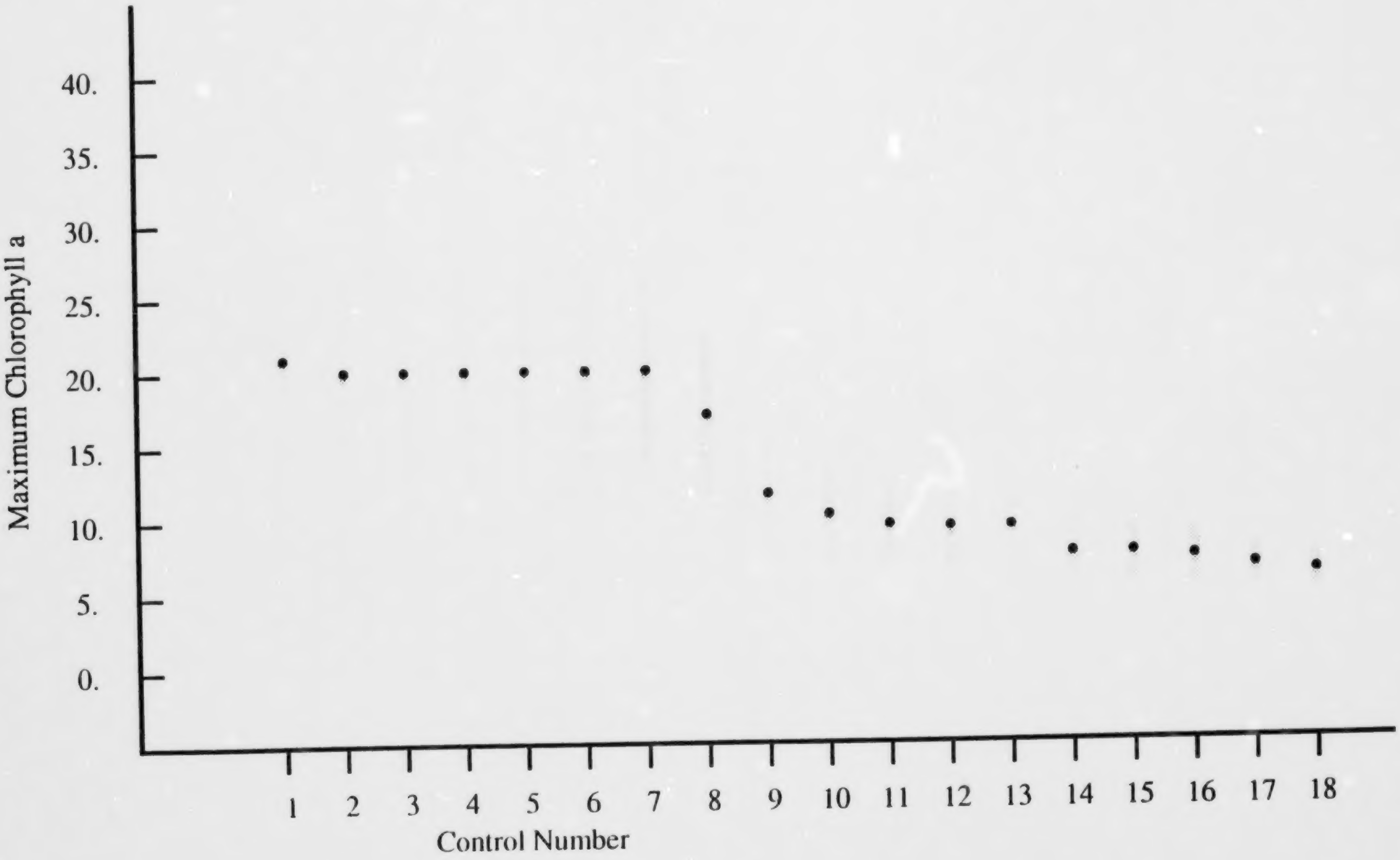
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8k
Chlorophyll Concentration in the Epilimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

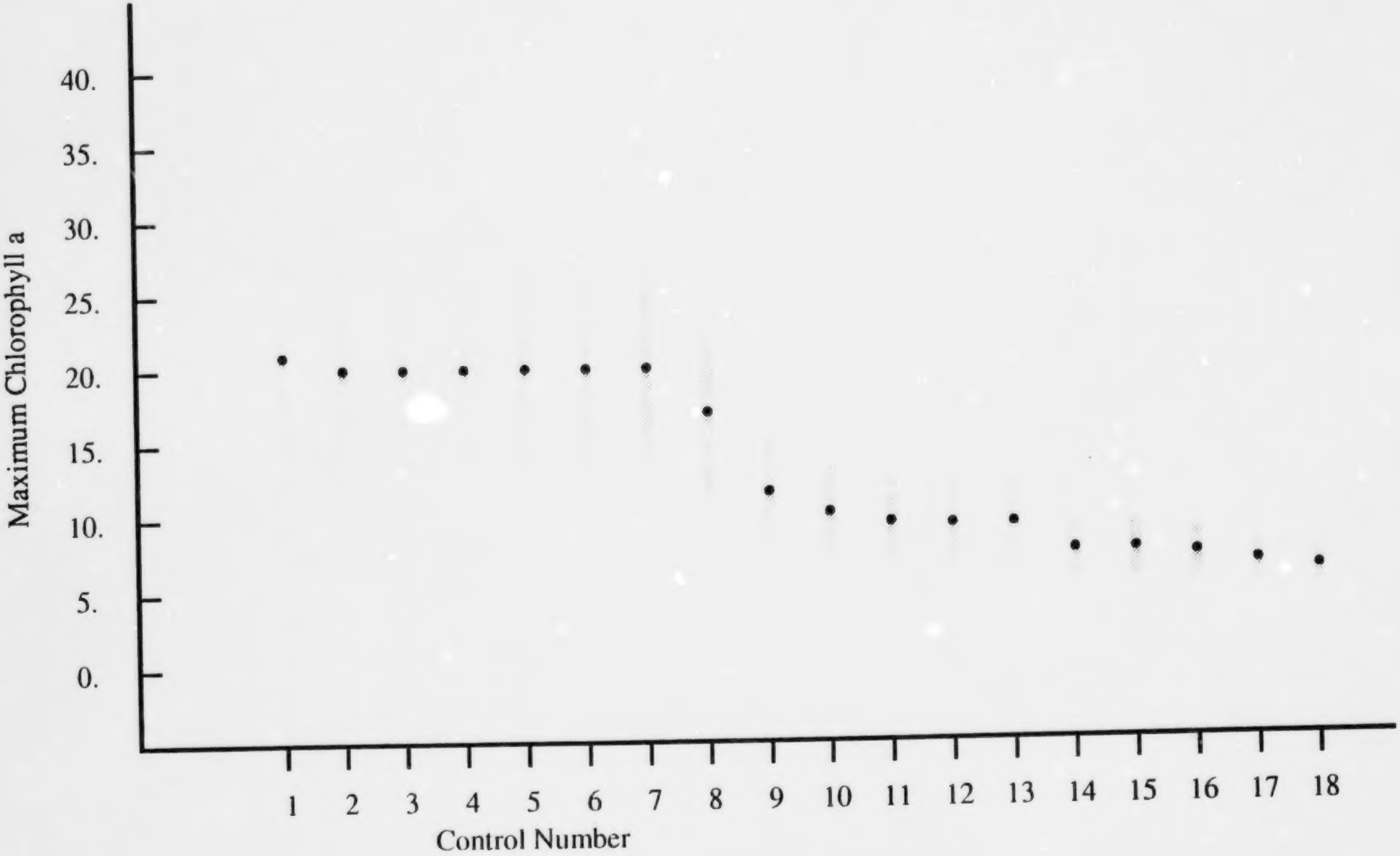
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.81
Chlorophyll Concentration in the Hypolimnion
During Summer for Eutrophication Scenario



OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

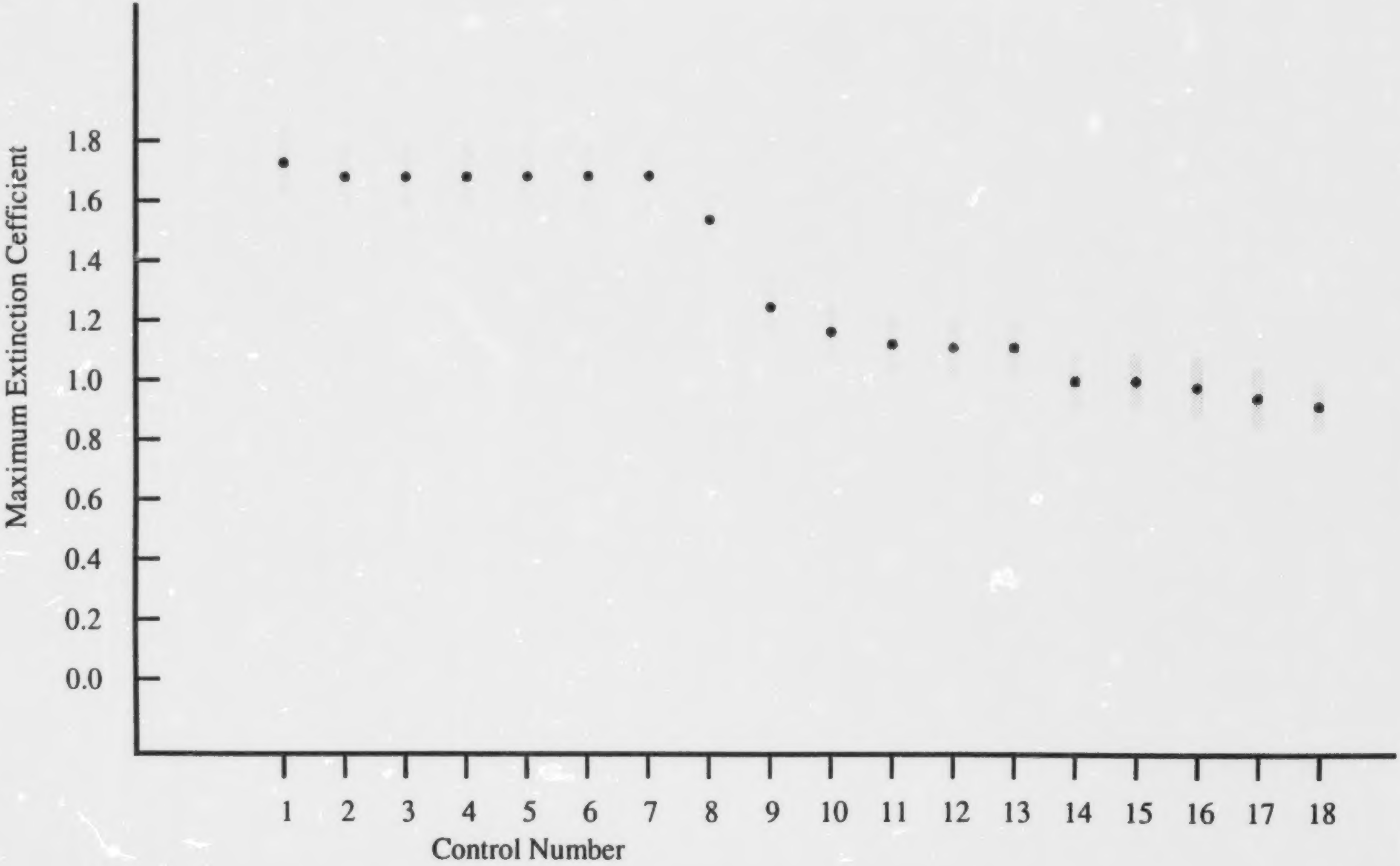
HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

OVERALL CONTROL OPTIONS

Control Number	Description
1	Initial
2	Chemical Precipitation - HWSTP
3	Nitrification - HWSTP
4	Nitrification - BSTP
5	Dofasco to Recycle
6	Dofasco to HWSTP
7	Stelco (Work in Progress)
8	Diffuse Source Control
9	Sand Filters HWSTP
10	Dual Point HWSTP
11	Sand Filters BSTP
12	Dual Point BSTP
13	Natural Control
14	Retention Basins (CSO)
15	Oxygen Injection
16	Dundas STP
17	Dredge Cootes Paradise
18	Discharge to Lake Ontario

HWSTP = Hamilton Wentworth Sewage Treatment Plant
BSTP = Burlington Sewage Treatment Plant
CSO = Combined Sewer Overflows

Figure 3.8m
Extinction Coefficient in the Epilimnion
During Summer for Eutrophication Scenario



point chemical addition of the Hamilton and Burlington Wastewater Treatment Plants), CSO Control Option 14, and discharge to Lake Ontario (Option 18).

The concentration calculation upon which these calculations are based, are summarized in Figure 3.9 (3.9a: Ammonia, 3.9b: Nitrate, 3.9c: Organic N, 3.9d: Soluable Phosphorus, 3.9e: Total Phosphorus, 3.9f: Chlorophyll, 3.9g: Light Extinction Coefficient). The figures show that mean calculated values as a select line and the calculated 95% confidence interval as a shaded area. The confidence interval is calculated assuming a Monte Carlo Simulation. A uniform distribution is used for the loadings while a triangular distribution is used for the various model coefficients. The range of the coefficient distribution was set based upon literature ranges.

3.4.9 - Qualitative Evaluation of Effectiveness of Remedial and Mitigative Measures

The impact of various remedial and mitigative control measures upon water quality in Hamilton Harbour were evaluated qualitatively using a seven level rating system. The assessment is given in Tables 3.12 and 3.13. The evaluation suggests that fishery end use receives some beneficial effect if most these control measures are implemented. These control measures improve the Harbour water quality by enhancing water clarify, desirable dissolved oxygen level and preventing metals and toxic containments from re-entering the water column. As a result, the Harbour can be restored to provide a littoral habitat for fishery.

These same control measures are less beneficial, if swimming and body contact sports are the desired end uses Only a few of these control measures (disinfection and CSO control) make the Harbour suitable for swimming by reducing the level of pathogenic bacteria. The evaluation suggests, however, that most point and non point source control measures (Table 3.13) have some effect upon swimming as well as recreational boating, body contact sports, and the industrial water supply. This results from their impact upon water clarity and other aesthetic factors, rather than upon bacterial concentrations.

The mitigating measures (Table 3.12) generally have a small effect upon end use, except for boating, education and fishing end uses. The prime effects are aesthetics and perception if toxic substances etc. are supressed successfully,and the possible up take of these contaminants by the fishery.

QUALITATIVE EVALUATION OF EFFECTIVENESS OF MITIGATIVE MEASURES
TABLE 3.12

+ positive control effect
- negative control effect
N - Negligible

Degree of Control Effect
- High (H)
- Medium (M)
- Low (L)

CONTROL MEASURES	DESIRED END USES								
	Recreational Boating	Swimming	Shipping & Navigation	Wildlife Habitat	An Educational Resource	Body Contact Sports	Fishery	Industrial Water Supply	Recipient of Acceptable Waste
1. Initial									
2. Oxygenation of Water Column	+ L	N	N	N	+ L	N	+ M	N	- L
3. Iron Addition to Harbour Water	+ L	N	N	+ L	+ L	N	+ L	N	- L
4. Lime Addition to Harbour Water	+ L	N	N	+ L	+ L	N	+ L	N	- L
5. Dredging and Disposal of Sediments	- L *	- L *	N	- L *	+ L	- L *	+ M	N	- L
6. Physical Sealing of Sediments with Clay	- L *	- L *	N	+ L	+ L	- L *	+ M	N	- L
7. Lime Treatment of Sediments	N	N	N	+ L	+ L	N	+ L	N	- L
8. Nitrate Injection to Sediments	N	N	N	N	+ L	N	+ L	N	+ L
9. Define ship lanes away from shallow areas to reduce disruption of bottom sediments	+ L	+ L	- L	N	+ L	N	+ L	N	N
10. Installation of Dykes to Cootes Paradise	N	N	N	+ H	+ H	N	+ H	N	- L **
11. Stocking and increasing pike population to prey on carp in Cootes Paradise	N	N	N	N	+ M	N	+ H	N	N

NOTE: * Temporary impact during effecting mitigating measure; otherwise negligible
** Effect in Cootes Paradise; negligible effect in Hamilton Harbour

QUALITATIVE EVALUATION OF EFFECTIVENESS OF REMEDIAL MEASURES CONSIDERED
IN OVERALL CONTROL SCENARIO
TABLE 3.13

+ positive control effect
- negative control effect
N - Negligible

Degree of Control Effect
- High (H)
- Medium (M)
- Low (L)

CONTROL MEASURES	DESIRED END USES								
	Recreational Boating	Swimming	Shipping & Navigation	Wildlife Habitat	An Educational Resource	Body Contact Sports	Fishery	Industrial Water Supply	Recipient of Acceptable Waste
1. Initial									
2. Chemical Precipitation - HWSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
3. Nitrification - HWSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
4. Nitrification - BSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
5. Dofasco Recycle	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
6. Dofasco to HWSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
7. Stelco (Work in Progress)	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
8. Diffuse Source Control	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
9. Sand Filters - HWSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
10. Dual Point Chemical Addition HWSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
11. Sand Filters - BSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
12. Dual Point Chemical Addition - BSTP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
13. Natural Control	+ L	+ L	N	N	+ L	+ L	+ L	+ L	- L
14. Retention Basins (CSO's)	+ L	+ H	N	N	+ L	+ L	+ M	+ L	- L
15. Oxygen Injection	+ L	+ L	-L or -M	N	+ L	+ L	+L to +H	+ L	- L
16. Dundas STP	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- L
17. Dredge Cootes Paradise	- L	- M	N	N	+ L	N	- H	N	- L
18. Discharge to Lake Ontario	+ L	+ L	N	N	+ L	+ L	+ M	+ L	- H
Disinfection	+ L	+ H	N	N	N	+ H	N	N	N

3.5 Assessment of Cost Effectiveness of Mitigating Measures for a Self-Sustaining Fishery

3.5.1 - Introduction

At the start of the project, documentation of the requirements for a self-sustaining fishery were not available in written form. Accordingly, as a part of this work, information was synthesized which permitted the development of hypotheses concerning requirements of a self-sustaining fishery and criteria for measuring the success of achieving the hypotheses.

A variety of discussions were held with scientists from the Federal Department of Fisheries and Oceans, the Federal Department of the Environment, the Provincial Ministry of Natural Resources, the Provincial Ministry of Environment, and the Royal Botanical Gardens. As well, discussions were held with designers of new marsh systems at Long Point and developers involved in the Perimeter Road and Lax Property.

Aspects considered in the discussions included:

- Assessment of fisheries goal;
- Target species;
- Identification of spawning, habitat and nursing areas and their requirements;
- Relationship of toxic compounds to fish yield;
- Hypotheses and implications; and
- Conceptual design of potential restoration methods.

From the discussions, an approach to development of the warm-water fishery, a set of hypotheses for testing, and the implications of the hypothesis were critiqued. These aspects are now discussed.

Approach to Development of Warm Water Fishery

Much is known about the Hamilton Harbour fishery and of potential methods for enhancement of a quality fishery. However, there are many unknown factors. Accordingly, the following approach would be useful for enhancing the quality of a self-sustaining, warm-water fishery.

1. Develop and finalize criteria for evaluating achievement of the Fisheries Goal.
2. Develop scientific hypotheses and ways of evaluating the experiment.

3. Layout options for management.

Hypotheses for Testing

From the historical perspective of there being a warm-water fishery in the Harbour, it is reasonable to hypothesize that:

i) The major factor limiting the present warm water fishery is the lack of suitable habitat for reproduction and rearing.

ii) Hatching is the key factor limiting the number of Pike in the Harbour.

iii) Hatching and adult habitat is the key factor limiting the number of Largemouth Bass in the harbour.

iv) Development of hatching and adult habitat will have a substantial impact upon the fishery, without substantive changes in water quality.

v) The major impact of water quality on development of a fishery is its impact upon water clarity and the associated development of macrophyte beds for adult pike habitat and juvenile and adult Largemouth Bass habitat.

vi) Other unknown factors such as currents along the exposure shoreline may cause the major differences in macrophyte densities observed along the North shore.

vii) The major impact of toxic substances is its affect on the edibility of the fish and human perception of the quality of that flesh, rather than on the extent (magnitude) of fish yield.

There are other factors which could impact the development of a warm water fishery. Further evaluation of these factors need to be researched to assure that the hypothesis advanced above are appropriate.

3.5.2 - Implications of Hypothesis for Cost Benefits Framework and Analysis

Gross fish yield is controlled by the area of suitable reproduction, nursing, and living (adult) habit. These hypotheses infer that the major limiting factors are reproductive and nursing habitat. Thus the magnitude of sustainable fish yield will be much more sensitive to expenditures spent upon nursing and reproductive habitat than upon changes in adult habitat and hence, upon improvements in water quality as expressed through changes in water clarity.

Accordingly, in the cost/benefit analyses, the benefit/cost ratio for expenditures spent on mitigating measures (such as fish reefs, wave barriers, development of a marsh ecosystem in the Grindstone Creek delta) would be much larger than the benefit/cost ratio for expenditures spent upon remedial measures (loading control).

It is recommended that these hypotheses be viewed as a hypotheses rather than proven facts. If the fishery restoration is developed along the lines described above, it is recommended that the restoration be viewed as an experiment with; (i) appropriate criteria for measurement being taken to check the hypothesis; (ii) criteria being developed for ascertaining the success of achieving the fisheries goal; and (iii) alternative options developed if different effects result from the restoration effort.

3.5.3 - Scenario of Mitigating Measures for Fishing Restoration

In the field of fisheries management, the techniques discussed here are called restoration techniques. In this report, they are described as either "restoration techniques", or as "mitigating measures" consistent with the terminology of the remedial action plan (RAP).

Fisheries restoration is assessed in this report for six areas (Figure 3.9) in Hamilton Harbour.

- The Grindstone Creek Upper Water (i.e., above Hamilton Harbour water level);
- Cootes Paradise (the open waters of the East Pond) the Perimeter Road area;
- the Lax Property;
- the Perimeter Road;
- the Burlington North Shore; and
- the Grindstone Creek Delta

While Grindstone Creek upper waters and Cootes Paradise are not in the Harbour proper (i.e., the waters of the Harbour, which are the main focus of the project), they must be considered as a part of the mitigating measures because they are key to the development of a self-sustaining warm-water fishery. That is, given the hypotheses developed above, all expenditures carried out to develop a self-sustaining warm-water

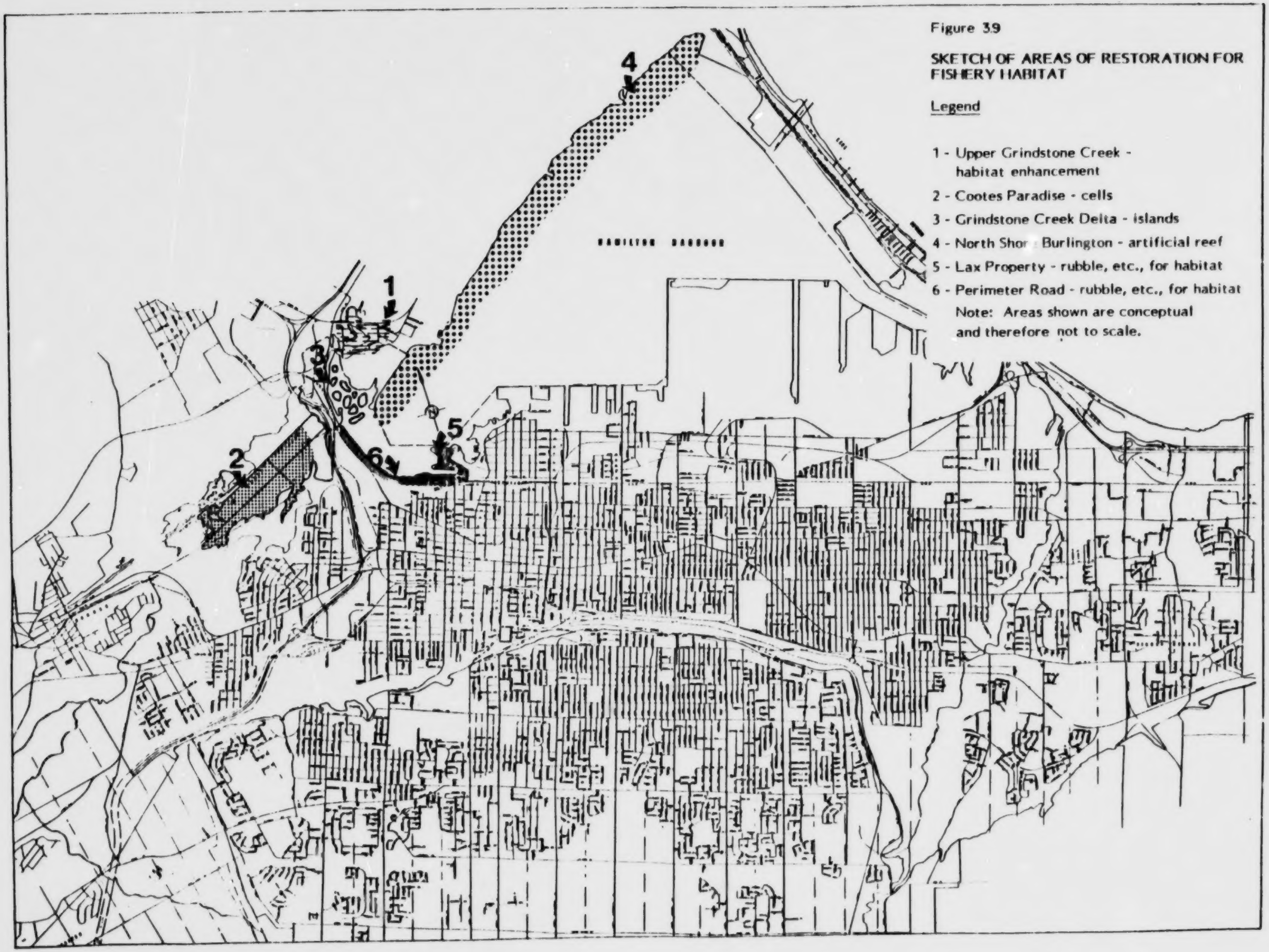


Figure 39

SKETCH OF AREAS OF RESTORATION FOR FISHERY HABITAT

Legend

1 - Upper Grindstone Creek - habitat enhancement
2 - Cootes Paradise - cells
3 - Grindstone Creek Delta - islands
4 - North Shore - Burlington - artificial reef
5 - Lax Property - rubble, etc., for habitat
6 - Perimeter Road - rubble, etc., for habitat

Note: Areas shown are conceptual and therefore not to scale.

fishery will probably be ineffective, unless these two areas are also considered as a part of the RAP.

A scenario for mitigating measures related to the warm water fishery is outlined below. The key to understanding the scenario is the following:

i) Pike spawning habitat is physically a different type of area than pike nursery and adult habitat. The literature indicates that the optimum ratio of spawning habitat to adult habitat is 0.25 to 1 (i.e., 1 ha to 4 ha; V. Cairns personal communication.)

ii) Largemouth Bass use the same habitat for spawning, nursing, and adults activities. The key here is the need for structures (old rubber tires, rubble, macrophyte beds) which they can use to defend for their eggs and where they are out of view from each other.

The basic approach for the scenario is to treat the creation of suitable physical habitat for spawning, nursing, and adult activities as the first requirement and then to assess the impact of point and non-point source control upon adult habitat.

3.5.4 - Description of Elements of Scenario

A summary of the options and the associated areas of Fish Habitat is given in Table 3.14. The estimated costs of each restorative action are given in Table 3.15. A sequence of restorative actions is given in Table 3.16 along with the cumulative estimates of yield of Largemouth bass and northern pike are compared to the estimates of cumulative cost of the mitigating (restorative) and remedial (point source control) measures.

The upper waters of Grindstone Creek are composed of 3 main area: Sunfish Pond, the Elbow below No. 2 Highway, and the pond above No. 2 Highway. The total area of these 3 ponds is approximately 19 ha; the area of each pond is respectively 3.2 ha, 9.3 ha and 6.0 ha. The lower two ponds are susceptible to water level variations while the upper pond is above long-term water level variations. The area occupied by plants in these ponds has declined from 2.6 ha, 6.9 ha, and 6.0 ha in 1934 to approximately 0.3, 0.7 and 3.7 ha in 1985. A reasonable hypothesis for explaining this decline (V. Cairns, P.C.) in habitat is the increase in water levels between 1934 and 1985 and the associated effect of wave action, siltation, and ice effects upon macrophyte beds.

TABLE 3.14

ESTIMATES OF HABITAT AREA FOR HAMILTON HARBOUR FISHING

Option	Total Area	Pike Hatching Habitat (ha)		Pike Nursing Habitat (ha)		Adult Pike Habitat (ha)		Bass Hatching & Adult Habitat (ha)	
		Now	Proposed Potential	Now	Proposed Potential	Now	Proposed Potential	Now	Proposed Potential
Grindstone Upper Water	19 ha	4.7	7	--	--	--	--	--	--
Cootes	210 ha	0	18	0	20	20	40	20	70
Perimeter Rd.	24 ha	--	--	--	--	2	24	2	24
Lax Property	19 ha	--	--	--	--	2	11	2	11
Burlington North Shore	142 ha	--	--	--	--	4	16/126	4	16/126
Grindstone Delta (to 2.7 m depth)	44 ha	0	2	0	14	0	14	0	14

TABLE 3.15

ESTIMATES OF COST OF REMEDIAL ACTIONS FOR FISHERIES

Options	Capital Cost ($)	O&M ($)	Annual Cost Equivalent ($) (20 Yr. Amort.)	Constant Dollar Cost Equivalent ($)
1. Grindstone Upper Water	0.1 million	10,000	.023 million	.017 million
2. Cootes Perimeter	1.0 million	50,000	.139 million	.122 million
3. Perimeter Road	1.2 million	10,000	.171 million	.096 million
4. Lax Property	0.5 million	20,000	.097 million	.056 million
5. North Shore Burlington	0.12 million	5,000	.021 million	.013 million
6. Grindstone Delta	0.2 million	10,000	.039 million	.024 million

TABLE 3.16

ESTIMATES OF YIELD FOR MITIGATING AND REMEDIAL ACTION SCENARIOS FOR FISHERIES

No.	Option	Estimate of Yield for Option (kg/yr)		Cumulative Estimate of Yield (kg/yr)	
		Pike	Bass	Pike	Bass
1.	Enhance Grindstone Upper	(4,000 Potential Fingerlings)	--	--	--
2.	Enhance Cootes Paradise	(20,000 Potential Fingerlings) Adults: 100 - 500	400-2000	100-500	400-2000
3.	Grindstone Delta	20-70	40-200	100-600	400-2000
4.	North Shore Burlington	40-200	100-500	200-800	500-3000
5.	Lax Property	--	--	200-800	500-3000
6.	Perimeter Road	--	--	200-800	500-3000
6. Prime	Existing Situation With Above Restorations	60-300	100-700	300-1100	600-4000
7.	Sand Filters in STP	20-100	60-300	200-1200	800-4000
8.	CSO Control	20-100	100-500	300-1400	800-4000

STP = Sewage Treatment Plants

CSO = Combined Sewer Overflows

The remedial measures proposed for upper Grindstone Creek are as follows. For Sunfish Pond, a berm would be constructed across its front to protect it from wave action; shaping and seeding could increase the area for pike habitat by 30% of the total area. Shaping and seeding in Elbow Pond would increase pike habitat by 30%. Some modification to the pond on #2 Highway would also improve spawning habitat. Based upon literature data, it is hypothesized that these improvements may increase Pike spawning from 2000 to 4000 fingerlings per year. The rational for this is detailed in the appendix.

The major proposed remedial action for Cootes Paradise is the construction of 4 cells to provide for Pike spawning and nursing habitat in 2 cells of size 60 ha and to provide for Largemouth Bass spawning and adult habitat in the other two cells of area 90 ha. These 4 cells would be designed to occupy about 80% of the total open water area of the East Pond. The remaining area of the total area of Cootes of 252 ha is occupied by marsh. It is assumed that 30% of the smaller two cells would be designed for Pike spawning habitat and that another 20 ha would be suitable for nursery or adult habitat for adult Pike; coupled with 50% of the existing marsh area, the total Pike habit is 40 ha (Table 3.14). For Largemouth Bass, it is assumed that approximately 50% of the larger two cells would provide bass habitat for a total of 70 ha when 50% of the existing marsh land in Cootes Paradise is included in the estimate.

The cost estimates are based upon the present Ducks Limited proposal which estimates approximately $200,000 to $300,000 for one cell of area 40 ha and $500,000 for two cells of area 60 ha. Values of $800,000 were originally estimated in the preliminary concept evaluation for construction of four cells in Cootes; a figure of $1 million (see Table 3.15) was chosen for use in this study for the four cells.

In addition to providing fish habitat, these cells would also provide benefit for waterfowl, potentially other land-based wildlife, and for suspended solids control. The first two cells, for pike habitat, could be constructed first in the shallowest western end of the East Pond. After a period of time when silt from Chedoke Creek and Spencer Creek have sufficiently filled in more of the pond, the last two cells would be built. Alternatively, all four cells could be built at once.

Each cell will have to be pumped dry once every five to ten years to achieve the desired effects upon vegetation (i.e., their ecology requires that the soil and root structures dry out periodically). This coupled with periodic berm maintenance will require some O&M costs on a continuing basis. The value given in Table 3.15 is an estimate.

The additional habitat for the Perimeter Road and the Lax Property is assumed to be constructed as a part of the two redevelopment proposals presently being pursued by the Region of Hamilton-Wentworth and the City of Hamilton respectively. The estimates of area of habitat associated with the Perimeter Road (see Table 3.14) are based upon creating optimum habitat to a depth of 3.5 m. The costs (Table 3.15) are based upon an estimate of 220,000 m^3 of fill being required (Dillion Engineering, personal communication) and the average Harbour dredging cost of $5 per cubic meter, and an additional $100,000 for rubble and other features. Similar assumptions are made for habitat around the Lax property, except it is assumed that only 60% of the perimeter would be suitable habitat due to the design of breakwalls and other architectural features. Rough estimates presently place costs for underwater work at the Lax property at $7 million; it is assumed that somewhat in excess of 5% of this cost would be required to create underwater habitat (Table 3.15).

The North Shore of Burlington provides the largest potential area of adult habitat in the whole Harbour (Table 3.14). However, the steepness of the shoreline, its openness to wave action, and the lack of features appear to be the largest inhibitor to the development of macrophyte beds. At present, for the harbour area from the North Shore around to, and including the Lax Property, only 24% has heavy macrophyte densities, while 23% has moderate densities, 38% has sparse densities and 15% has none. It is hypothesized that waves and sediment erosion are the major factors limiting the development of optimum beds around the periphery of the Harbour. This, combined with the relationship between fish production and different macrophyte densities (see Appendix 2), limits fish yield to approximately 40% of optimum.

At present, optimum or near optimum macrophyte densities occur in only a few areas, along the North Shore including the Lasalle Marina. The major restorative technique proposed for the North Shore is the installation of 12 sets of brush bundles and rock-rubble underwater reefs which may create 1 ha per set of optimum macrophyte densities and hence fish habitat. Each set would cost approximately $10,000. The order of magnitude estimate for O&M costs is $5,000/yr. (Table 3.15). It is assumed that existing habitat and brush bundles/artificial reefs would result in 12 ha of optimum habitat (Table 3.15).

The remaining, non-restored, area of the North Shore is 126 ha. Macrophyte beds may develop in this area depending upon the depth of light penetration. Improvements of light penetration is assessed in Table 3.16 as a function of control of point and diffuse sources.

The proposed restorative technique for the Grindstone Creek delta consists of construction of islands upon which submergent/emergent vegetation could develop. The area of Grindstone Creek considered (See Figure 3.8) is the water area to a depth of 2.7 m (i.e., at its mouth). The top of the islands would be seeded. Scirpus and Spargianium are candidate plants. During years of low water, the top of the islands would be completely out of the water, while during high water, the top of the islands would be somewhat below water. During low water level years, vegetation would develop down the slope of the island.

It is assumed that 5% of the area may be a reasonable estimate of spawning habitat for both pike and bass. The estimates for cost of construction (Table 3.15) are based upon moving 40,000 m^3 of material at $5 per m^3. It is suggested that the islands be placed to aid channelization of silt coming from Grindstone Creek. The islands could be constructed from material from the bottom of the basin.

An alternative design involving the placing of a tire breakwall across the mouth of Grindstone Creek was also considered. Analysis of the resultant wave energy indicated, however, that sediment erosion would still prevent development of macrophyte beds. Accordingly, the island concept was developed to act as a nucleus for plants which could adjust to different water levels, to protect extensive areas from wave action, and to aid channelization of the inflowing silt load from Grindstone Creek out to the main bay. As well, inspection of aerial photos suggest that part of the turbidity plume from Cootes Paradise is transported into Grindstone Creek delta. Over the long term, the Grindstone Creek should be the main source of silt in the Grindstone Delta because gravity will carry silt from Cootes out into the deeper bay areas. However, transient inputs from Cootes to the Grindstone Delta are possible. An island could be placed at the mouth of the delta to minimize the inputs of silt from Cootes.

The sequence of restorative measures (Options 1 to 6, Table 3.16) roughly meet the empirical criteria of 0.25 ha of spawning habitat for every ha of adult habitat for pike. The total potential area for spawning habit is 27 ha (See Table 3.14). The total optimum adult area is 56 ha (40 ha in Cootes, 16 ha along the north shore). In addition, there is 175 ha of suboptimal habitat in the Perimeter Road, Lax Property, Burlington North Shore and Grindstone delta areas; the actual optimal habitat is a function of light penetration and wave effects. For present conditions (i.e., with no point source control), light penetration results in an additional 47 ha of habitat for a total of 103 ha. Thus, the ratio would be 27:103 which is approximately .26:1. With point source control, remedial measures would increase water clarity and give additional adult habitat of approximately 40 ha; this gives a spawning area to adult habitat area ratio of 0.19:1 (i.e., 27 ha to 143 ha). These values, however, ignore the effect of waves and other factors upon habitat. Along the north shore, the optimal area is equivalent to approximately 40% of the total area. Thus waves cause present conditions to have an areal ratio of 27:75 (where 75 = 56 + 0.4 x 47) or 0.36:1 and point source control to have a ratio of 27:91 (where 91 = 56 + 0.4 x 88). or 0.3:1.

Overall, it is concluded that the ratio of hatching habitat to adult habitat is within the range suggested by the literature. This ratio can, however, be developed only if substantive spawning habitat is developed in Cootes Paradise. There are no other suitable areas; the potential areas in the Grindstone Creek Upper Delta are not large enough. If only the Grindstone Creek area were restored, restoration of a limited area in the Harbour proper of approximately 30 ha would be justified. Alternatively, if only Grindstone Creek is restored, it is hypothesized that the fishery would not be self-sustaining. Rather, it would have to be hatchery supported.

One other word of caution is in order. Within the field of fisheries management in Ontario, in Canada, and possibly in North America, it is our understanding that the success of restoration of such an urban fishery has not been demonstrated. Accordingly, the restoration of the whole Harbour fishery should be viewed as an experiment with proper hypotheses being formulated, criteria for assessing the success of the experiment specified before its initiation, and methods for measuring the scenario of the experiments being established a priority.

3.5.5 - Results

The estimates of yield of a cumulative sequence of remedial and mitigating measures for fisheries are given in Table 3.16 for the following sequence of measures:

1. Enhance Grindstone Upper (Grindstone Creek Above the Harbour)
2. Enhance Cootes Paradise

3. Enhance Grindstone Creek Delta
4. Enhance North Shore of Burlington
5. Enhance Lax Property
6. Enhance Perimeter Road

6 Prime Existing Situation With Above Restoration

7. Cumulative Effect of Point Source Control to Option 9: Sand Filters on Hamilton - Wentworth Sewage Treatment Plant
8. Cumulative Effect of Point and Diffuse Source Control to Option 14: Combined Sewers Overflow Control.

Measures 1 to 6 represent the potential effect of the restorative measures on pike hatching and fingerling production, and on adult pike and adult bass yield. The yield estimates for measures 1 to 6 are based upon light independent components. The 6 prime measure represents the additional pike and bass yield due to light penetration under current loadings to the Harbour, if the restorative techniques (measures 1 to 6) were used to create the maximum potential adult habitat down to a depth of 3.5 metres. Light independent yield results from restoration of Cootes Paradise and the Grindstone Delta in which light penetration has no effect upon fish yield estimates. Light penetration has an effect upon fish yield in the Perimeter Road and Lax property. The North Shore of Burlington have both light independent (under water structures) and light dependent effects upon fish yield (see page Appendix F).

Measures 7 and 8 represent the additional yield resulting from the cumulative effect of remedial measures described in the previous section and the associated cumulative cost. Measure 7, which represents the cumulative effect of point source control to and including Option 9 of the Eutrophication scenario, includes the effect of nitrification in the Burlington and Hamilton - Wentworth Sewage Treatment Plants, industrial cleanup and implementation of sand filtration at the Hamilton-Wentworth Sewage Treatment Plant. Measure 8, which represents the cumulative effect of point and diffuse source control to and including Option 14 (storage of Combined Sewers Overflows) of the Eutrophication scenario, includes the additional effect of sand filters at the Burlington Sewage Treatment Plant, natural cleanup processes, and storage of Combined Sewers Overflow's from the downtown and industrial areas of Hamilton. Control Option 13 (Natural Cleanup) of the Eutrophication scenario is not properly modelled in the Ng model2) because changes in phosphorus, ammonia, and nitrate fluxes with the sediments over time are not considered in the modelling methodology, described in the previous section. However, its effect should be small in the overall evaluation of the impact of Option 13 upon light penetration.

Measures 7 and 8 were chosen for evaluation in the self-sustaining, warm-water fishery because they represent points in the cost-effectiveness curve for adult habitat where substantive improvements in light penetration result (see Figure 3.7a) in the Eutrophication scenario.

The procedure for estimating the yield of Northern Pike and Largemouth Bass are given in Appendix 2. For the hatching of Northern Pike, a range of 200 to 1200 pike fingerlings have been observed to develop per acre of spawning habitat in various management areas. In this report, it was assumed that 500 fingerlings per acre could result. The yield estimates are based upon the reservoir management literature which suggests that 30 kg of Largemouth Bass per ha per year can develop in optimum macrophyte densities of 50 kg. (dry weight) per ha and that 13 kg of Northern Pike can develop per year per ha.

The possible yield for each mitigating/remedial measures are given in Table 3.16 as the upper end of the range. The lower end of the range is based upon assuming that a probable range is 20% to 100% of the possible yield. The cumulative yield estimates do not exactly equal the numerical values of the individual measures due to the attempt to use only one figure accuracy in constructing the table.

The yield estimates given in Table 3.16 for Northern Pike indicates that of the order of 20,000 fingerlings may develop and of the order of 600-3000 adult Pike assuming an average weight of 0.5 kg/adult. The relative number which would grow from fingerlings to adulthood requires further assessment.

The yield estimates for Pike and Bass should be viewed with some circumspection in view of the lack of significant numbers of Pike and Bass in 1987. Pike spawning has been observed in Grindstone Creek above Highways 2 and 52, while Largemouth Bass have been found mainly in the Lax Property area. The observed numbers of Pike and Bass, which are two orders of magnitude below the potential yield estimates indicated in Table 3.16, may challenge the credibility of the estimate of Table 3.16. However, electroshocking in Cootes Paradise needs to be carried out to give good estimates of the numbers and mass of fish because Cootes may contain many of the Pike and Bass found in the Harbour ecosystem. Furthermore, accepting the hypothesis that hatching habitat for Northern Pike and hatching/adult habitat for Largemouth Bass are limiting current conditions, a substantive increase in numbers of these two species is expected. Finally, these two species are top species in the food chain and indicators of other quality species. Hence, as indicators of other quality species with similar ecology, these yield estimates would be reasonable.

It is possible also that growth of other species would result in higher overall estimates of sport fish productions. However, for comparable reservoirs in the mid U.S.A. with chlorophyl levels similar to those of the Harbour (i.e., of the order of 35 ug/L), the total sportfish yield was approximately 90 kg/ha/yr with a 90% confidence interval of 60-140 kg/ha/yr (Jones and Hoyer, 1982). When different sunlight factors (Schlosinger and Regier, 1982) are taken into account, an upper limit for production of the order of 50 kg/ha/yr in the Harbour may be a reasonable limit. Accordingly, the upper limits of yield in the Harbour given in Table 3.16 are reasonable because they are based upon 13 kg Pike/ha/yr plus 30 kg Bass/ha/yr.

The fish yield from the different mitigating and remedial actions are compared to the cumulative costs of options in Table 3.17. The first column gives the cost in present dollars while the second column gives the cost in constant dollars. Present dollars are analogous to the cost of a mortgage with the annual cost of paying off capital decreasing as a percent of total income keeps pace with inflation. Constant dollars represent an increasing payment annually to keep the total payment constant when the effects of inflation are accounted for.

TABLE 3.17

COMPARISON OF FISH YIELD AND COSTS FOR MITIGATING AND REMEDIAL ACTIONS

No.	Option	Cumulative Estimate of Yield (kg/yr) of Option		Cumulative Cost in Present Dollars (Million Dollars)	Cumulative Cost in Constant Dollars (Million Dollars)
		Pike	Bass		
1.	Enhance Upper Grindstone	--	--	.023	.017
2.	Enhance Cootes Paradise	100-500	400-2000	.16	.14
3.	Grindstone Delta	120-600	500-2300	.20	.16
4.	North Shore Burlington	200-1000	600-3200	.22	.18
5.	Lax Property	200-1000	600-3200	.32	.23
6.	Perimeter Road	200-1100	700-3400	.49	.33
7.	Sand Filters in Hamilton STP (Option 9 of WQ Scenario)	200-1200	700-3700	10	5.0
8.	CSO Control (Option 14 of WQ Scenario)	300-1400	800-4200	20	11

The cost-effectiveness of the sequence of mitigating and remedial measures can be judged by inspection of Table 3.17. The mitigating measures for the six habitat restorative options (Upper Grindstone Creek, Cootes, Grindstone Delta, Burlington North Shore, Lax Property, Perimeter Road) are over an order of magnitude more cost effective than the remedial measures considered. The estimates suggest that the objective of a self-sustaining, warm-water fishery is much more elastic for expenditures upon mitigating measures than for expenditures upon remedial measures.

However, the mitigating measures are goal specific, directed towards the self-sustaining warm water fishery goal, while the remedial measures are broader in their focus with potential benefits for several other factors including toxicity concerns and edibility of fish. The impact of remedial measures on toxic substances is being analysed in a preliminary fashion and summarized in a later section of this report. The other benefits from the remedial measures and the resultant economic perspective are assessed in Chapter 4 of this report.

3.6 Assessment of Cost Effectiveness of Control of Toxic Substances

3.6.1 - Introduction

A framework for assessing the impact of remedial and mitigating measures upon toxic substances requires the following elements to quantify cost-effectiveness and to provide input into the economic framework.

i) the toxic substances of most concern to human and ecological health must be defined;

ii) the levels of inputs and the concentrations of these substances in various biota and geochemical reservoirs (e.g., water, sediment) are model;

iii) the effect of control on loadings and on in place pollutants must be quantified;

iv) the effect of these measures upon the various ecological niches (including the fishery in the case of assessing a self-sustaining edible fishery) must be quantified;

v) the benefits to humans (or the decrease in risk due to exposure to such toxic substances) must be quantified;

vi) the value of these benefits to humans must be assessed either quantitatively (for economic purposes) or qualitatively (for assessing intrinsic benefits);

The establishment of such a framework and its implementation was started in this study. It was not feasible to build such a framework into the cost-effectiveness or a cost-benefit analysis of this study for the following reasons:

i) The target compounds to be used for an assessment could not be established because recent measurements of the various trace metals and synthetic organic chemicals in fish were not made available to this study at the conclusion of the study. In addition, only limited data exist for the body burden of these substances in various biota.

ii) Loadings of various possible subtances (e.g. mercury, PAH's) are known imprecisely; accordingly it is not possible to quantify, with much assurance the change in inputs which would occur with the implementation of the various remedial measures considered in Section 3.4. Loadings of other possible target substances (e.g., zinc, copper) are known in much better fashion.

iii) The potential response to in place contaminants in the sediments is known imprecisely without constructing appropriate mathematical models. Techniques for formulating such models are available, but have not been constructed nor tested on the Harbour. Accordingly, the confidence that we have in such tools requires further assessment.

iv) Tools for assessing the potential benefits to humans in terms of risk reduction are evolving. The synergistic effects of various compounds are not well understood.

v) The impact of the toxic substances on various ecological niches are being researched. This information is required to develop an understanding of the benefit to the ecosystem.

vi) The formulation of the impact of toxic substances control into an economic framework can be done qualitatively but not quantitatively. Furhter research into the human perception of "gut toxic substances" out at any cost, as stated by stakeholders, is required to provide information for the economic assessment outlined in Chapter 5.

Accordingly, in this remainder of the section, an approach to the assessment of risk from toxic substances is presented and an estimate of costs of controlling toxic substances in sediments is presented. The degree to which remedial measures considered in Section 3.4 are effective in reducing inputs to toxic substances to the Harbour is not considered. The effectiveness of mitigative measures which are costed, required further analyses before presentation in this document.

3.6.2 - Framework for Assessment of Risk From Radiological Substances

Radioisotopes of various elements may pose a health hazard to humans through external (beach walking, swimming, showers) and internal (drinking water, food) pathways. The radiological impact to humans can be assessed quantiatively through a methodology which has been developed by radiologists. The methodology assesses the potential radiation damage to various tissues and organs in the body. For our purposes, this information can be reduced to the following:

i) The risk to humans is assessed using units of Sieverts (Sv).

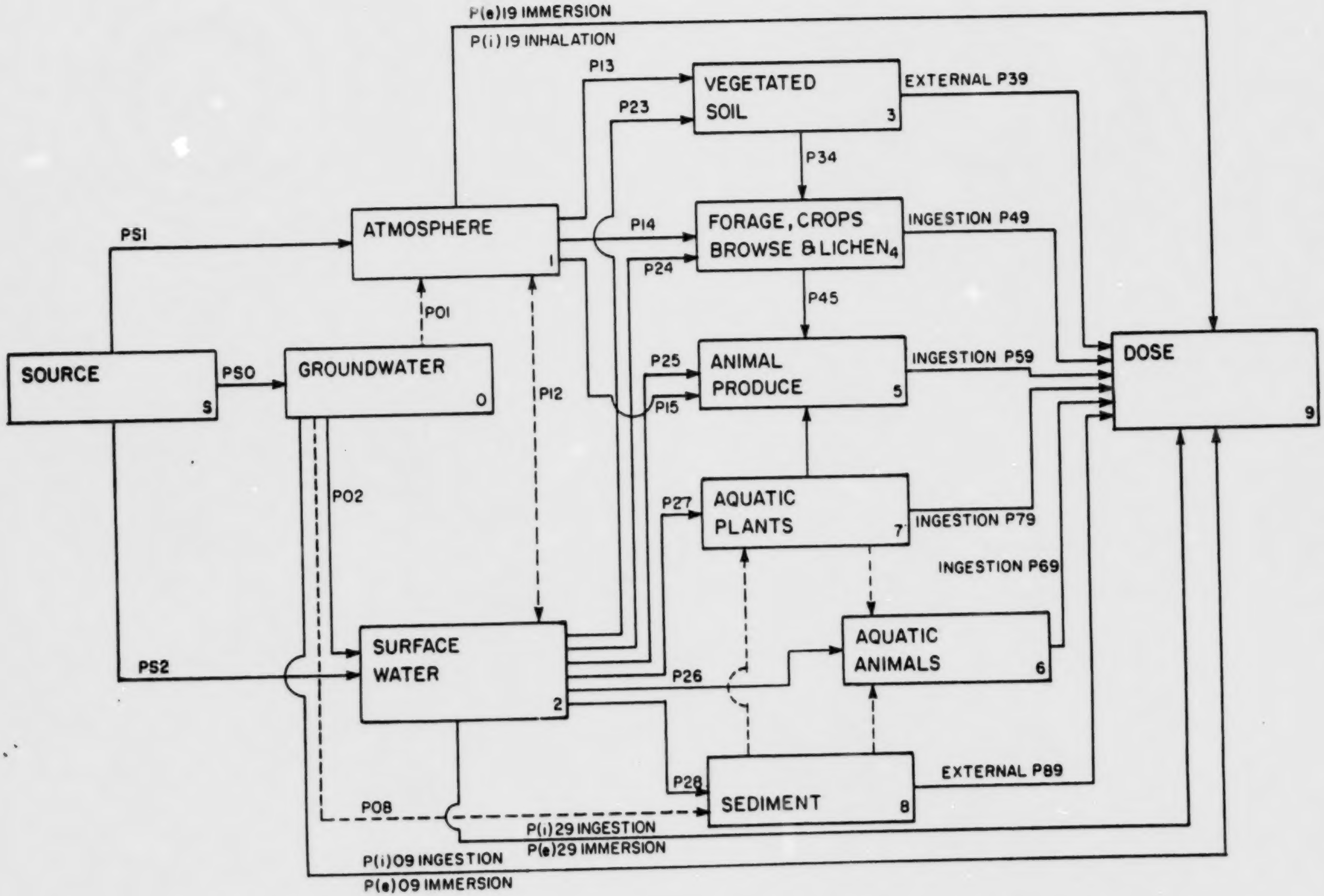
ii) The concentration of various radioisotopes in water, sediments, biota and humans is measured using units of radiological activity called Becquerel (Bq). For example, the concentration in water has units of Bq/L rather than mg/L.

iii) The degree of exposure to humans is related to the body burden using a set of dose-conversion factors (DCF), developed by radiologists. Different radioisotopes have different DCF's.

The Cities of Hamilton and Burlington have a variety of research and hospital facilities which utilize radioisotopes in their studies and for treatment protocols respectively. Many of the isotopes are injected into patients and then excreted either in urine or in stool. In many cases, these low-level radioisotopes cannot be collected for special disposal resulting in small quantities being excreted or disposed directly into the sewage system.

A study was undertaken (BEAK; 1988, Eedy et al., 1986) for the Canadian Atomic Energy Control Board to asssess the impact of the disposal of these radionuclies through the sanitary sewer system, landfills and incinerators. The pathways and biochemical compartments evaluated are given in Figure 3.10(a), the location of the major sewage treatment plants, landfills, and incinerators selected are indicated in Figure 3.10(b). The radioisotopes considered were:

- tritium (H-3),
- carbon-14 (C-14),
- phosphorus-32 (P-32) and phosphorus-33 (P-33),
- sulphur-35 (S-35),
- chromium-51 (Cr-51),


P(e)19 IMMERSION
P(i)19 INHALATION
P13
P23
VEGETATED SOIL 3
EXTERNAL P39
P34
ATMOSPHERE 1
PS1
P14
P24
FORAGE, CROPS BROWSE & LICHEN 4
INGESTION P49
P45
P01
SOURCE S
PS0
GROUNDWATER 0
P12
P25
P15
ANIMAL PRODUCE 5
INGESTION P59
DOSE 9
P02
P27
AQUATIC PLANTS 7
INGESTION P79
INGESTION P69
SURFACE WATER 2
PS2
P26
AQUATIC ANIMALS 6
P28
SEDIMENT 8
EXTERNAL P89
P08
P(i)29 INGESTION
P(e)29 IMMERSION
P(i)09 INGESTION
P(e)09 IMMERSION

Generalized Environmental Transfer Pathway Diagram

FIGURE 3.10(a)

Municipal Systems of Hamilton-Burlington Area and Hydrological Pathways of Receiving Waters

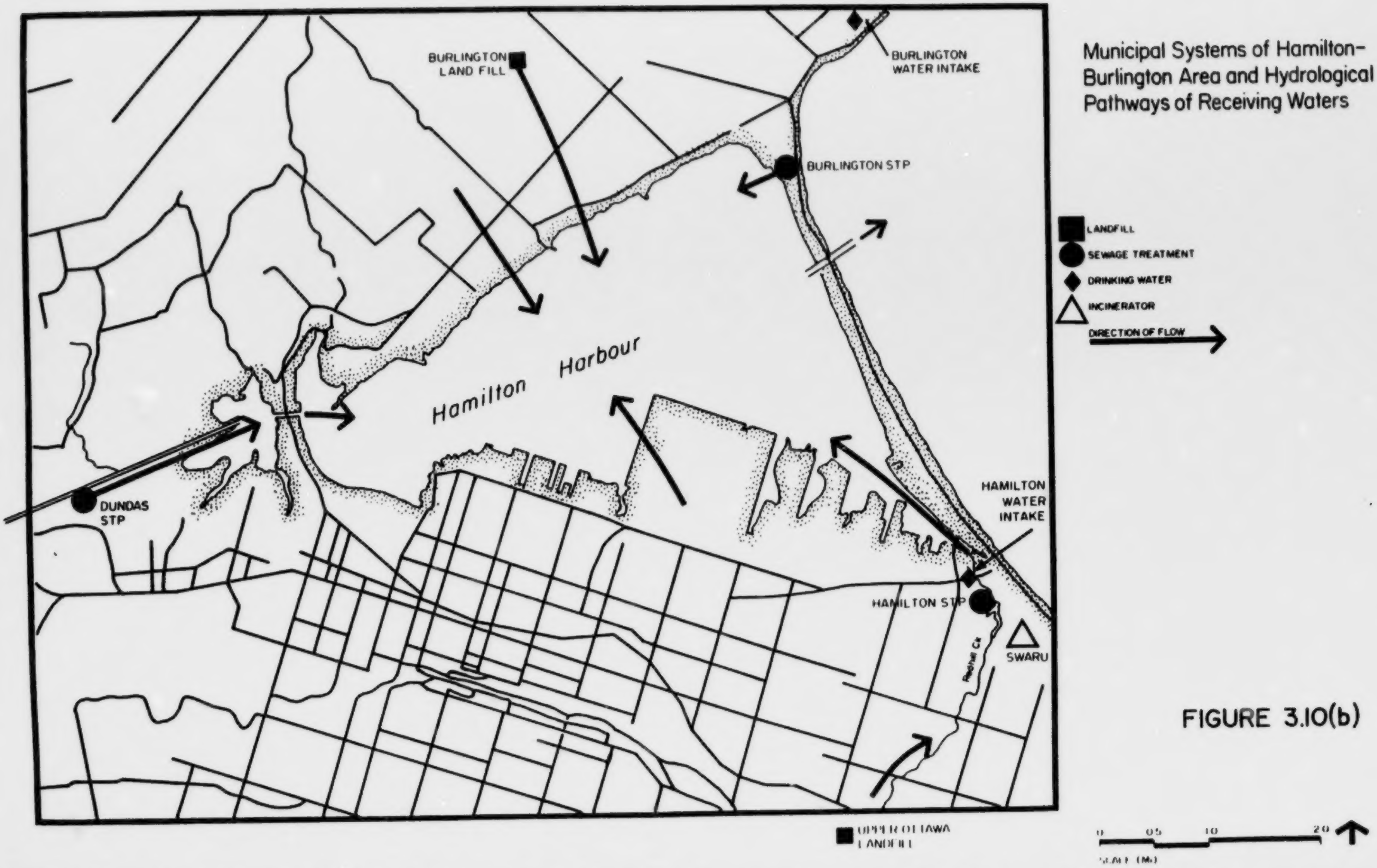

BURLINGTON LAND FILL
BURLINGTON WATER INTAKE
BURLINGTON STP
Hamilton Harbour
DUNDAS STP
HAMILTON WATER INTAKE
HAMILTON STP
Redhill Ck
SWARU
UPPER OTTAWA LANDFILL
LANDFILL
SEWAGE TREATMENT
DRINKING WATER
INCINERATOR
DIRECTION OF FLOW
0
0.5
1.0
2.0
SCALE (Mi)

FIGURE 3.10(b)

- cobalt-57 (Co-57),
- nickel-63 (Ni-63),
- zinc-65 (Zn-65),
- gallium-67 (Ga-67),
- selenium-75 (Se-75),
- technetium-99m (Tc-99m),
- iodine-125 (I-125),
- iodine-131 (I-131),
- thallium-201 (Tl-201),
- polonium-201, (P0-201)
- americium-241 (Am-241).

An inventory was conducted of the research laboratories, medical treatment centres, industrial and domestic sources of such wastes to determine the types, volumes and methods of their disposal. Computer models were then used to trace the radioisotopes through the worst-case exposure potential to both municipal workers and the public. A summary of pertinent results is presented below.

The assumptions used in the study were conservative, following the theory that if calculations assuming the maximum potential exposure result in acceptable risk levels there is nothing to fear. At the Hamilton Sewage Treatment Plant, dosimetry was calculated for workers in the aeration and sludge areas as well as ash loaders and truck drivers at the sludge incinerator. In addition, dosimetry was calculated from all waste treatment sources for the most highly exposed members of the general population. The maximum total potential exposure was calculated by assuming that workers were also members of the population and thus adding the two calculated doses. These results are summarized in Table 3.18.

The highest annual dose was calculated for the aeration worker who is also a member of the critical population. Other worker dose calculations were slightly lower. This maximum potential does of 2.0×10^{-6} Sv/a/p (2.0 u Sv/a/p) compares to the regulated maximum annual exposure for the general public (a level felt to be safe) of 5×10^{-3} Sv/a/p (5,000 u Sv/a/p). It also compares to average natural background radiation levels in North America (Wenk, 1980) of about 1.1 m Sv/a/p (1,100 u Sv/a/p).

TABLE 3.18

TOTAL MAXIMUM POTENTIAL RADIOISOTOPE DOSE CALCULATED FOR SEWAGE TREATMENT PLANT WORKERS WHO ARE ALSO MEMBERS OF THE CRITICAL POPULATION (Sv/a/p)

Persons	Maximum Annual Dose (Sv/a/p)
Aeration Workers	2.0×10^{-6}
Sludge Workers	1.3×10^{-6}
Ash Loaders	9.8×10^{-7}
Ash Truck Drivers	1.2×10^{-6}
Critical Members of General Population*	7.7×10^{-7}

* Included in worker dose calcualtion.

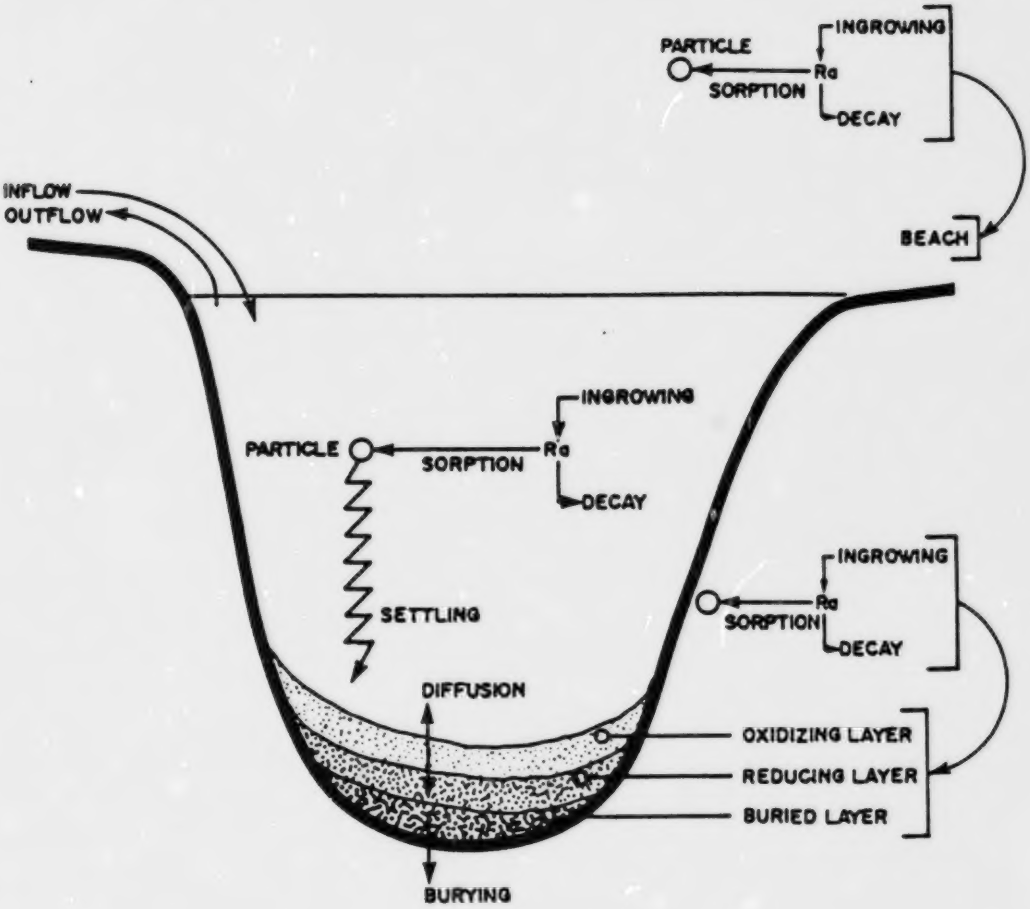
Thus, the maximum dose is only about 1/500 or 0.2% of the exposure from natural sources and 1/2500 or 0.04% of the regulated limit. For this reason, it was concluded that incidental disposal of radiosotopes into the Hamilton sewage system poses no risk to workers nor to the public.

3.6.3 - Framework for Toxic Substances

The limnological pathway model used for the radioisotopes is given in Figure 3.11. A similar pathway model was initiated for toxic substances but not completed at the conclusion of this study. Its development would aid in finalizing an assessment of cost-effectiveness of remedial and mitigating measures.

3.6.4 - Cost Factors Related to Remedial and Mitigative Measures for Toxic Substance Control

The major costs requiring assessment are those related to mitigative measures as the major remedial measures and their costs were detailed earlier. Costing data for the various mitigative measures were not available for Hamilton Harbour. Accordingly, data synthesized for the Bay of Quinte are used as a preliminary data base.


PARTICLE
INGROWING
Ra
SORPTION
DECAY
BEACH
INFLOW
OUTFLOW
INGROWING
PARTICLE
Ra
SORPTION
DECAY
INGROWING
Ra
SORPTION
DECAY
SETTLING
DIFFUSION
OXIDIZING LAYER
REDUCING LAYER
BURIED LAYER
BURYING

PATHWAYS DIAGRAM FOR TOXIC SUBSTANCES (RADIONUCLIDES)

FIGURE 3.11

The plausible options for consideration include:

- null option (allowing sediments to clean themselves up as point source control is initiated);
- alum injection;
- iron injection;
- lime addition;
- oxygenation; and
- dredging.

Based upon the unit area costs for the Bay of Quinte, the following costs (on an annual basis in present dollars) would result:

• Null option (allow natural cleanup)	No cost (included in point source control estimates)
• Alum injection (assuming injection every 3 years)	1 to 2 million/year
• Lime addition (assuming injection every year)	1 to 2 million/year
• Oxygenation (assuming addition every summer for two units)	0.2 to 0.3 million/year
• Sediment burial (once very ten years)	1 to 2 million/year
• Dredging (10 year amortization period; volume dredging is 6.2 x 10^6 m^3; disposal costs are assumed to be 15 percent of dredging costs)	6 to 7 million/year

To establish the effectiveness of these options, their relative ease of implementation and their detrimental effect, additional studies are required.

3.7 Assessment of Cost Effectiveness of Remedial and Mitigative Measures for a Swimming End Use

The overall sequence of remedial and mitigative measures considered in Section 3.4 for eutrophication control also enhances the potential for swimming in the Harbour. However, the actual effectiveness of the control measures is not known quantitatively without source-receptor modelling and without a bacterial budget for the bay. Such work is required in light of findings later in this study that the "swimmability of the harbour" is one use which has a potentially large economic value, especially non-use values.

The major points along the sequence of 18 control measures of the eutrophication scenario where marked improvement in the "swimmability of the harbour" would occur are Measure 9 (Sand Filters at the HWSTP), Measure 14 (CSO Control) and Measure 19 (Discharge to Lake Ontario). With the implementation of sand filtration, a substantial reduction in the discharge of fecal coliforms, the parameters for assessing swimmability by the wastewater treatment plant, should occur. CSO control would result in reduction of another major source of bacterial discharges from the STP's.

For swimming, accordingly, the following sequence of remedial and mitigative measures would be useful for consideration.

1. Improved Disinfection of the STP (cost of the order of $0.2 million/yr.).
2. Sand filtration at Hamilton STP ($9.7 million in present dollars, $6.2 million in constant dollars).
3. Retention basins for CSO control ($19.6 million/yr. in present dollars, $11.9 million/yr. in constant dollars).
4. Creation of swimming beaches:
   - 425 metre beach at Hamilton Island Lagoon;
   - two 50 metre beaches along the Burlington shore; and
   - 100 metre beach at Lasalle Parks (estimated cost is $0.5 million capital excluding land acquisition costs with O & M of $0.25 million/yr.)
5. Curtains around beach areas and disinfection within the curtains (estimated capital cost of $0.15 million, and O & M of $0.1 to $0.5 million/yr.).

The costs for the swimming beaches are based upon $0.5 million for creation of 1.5 km^2 of fill and underwater habitat of the Perimeter Road, an area of 1.5 km^2 above and below water level being filled to create these beach areas and an assumption of 10 life guards per 500 m beach working 10 hr. days for 90 days. The cost estimates given above include costs of the Hamilton Island beach as well as the three Burlington area beaches. The capital costs ($0.15 million) of the curtains are based upon assuming 2 km of curtains, 2.5 m wide are required to isolate the beach waters from Hamilton

Harbour and a unit cost of $25/m (the value assumed for the Bay of Quinte costing study).

The first measures would cause source improvement in bacterial levels, but may not be sufficient. Sand filtration, likewise, will cause some improvement, but may not be sufficient. However, the sand filtration measure of the eutrophication sequence is probably required to improve water clarity and other aesthetic conditions to make the water ameable to attracting swimmers. CSO control should reduce the bacterial levels significantly; but whether sufficiently low bacterial levels would be attained is unclear. It is possible that control of fecal coliform levels in stormwater discharges may be required to achieve a swimmable water, since stormwater typically has 10,000 to 100,000 organisms per 100 ml compared to a swimming standard of 100 organisms per 100 ml. In particular, bacterial impacts from the Rambo Hagor diversion in Burlington may cause closure of the Burlington Beaches; if so, placement of curtains around the beach area and disinfection within would be necessary (option 5 listed above).

An alternative sequence would be options 4 and 5 without point source control (options 1, 2 and 3). This would make the Harbour "swimmable" in defined areas, but water clarity and other factors related to eutrophication (algal mats, scum, etc.) may preclude attracting to many swimmers.

Another control measure which should be considered would be changing the organism used for assessing "swimmability" of water. Fecal coliforms are one parameter currently used; however, it includes organisms for both human waste, animals, woodlands and other terrestrial areas. A parameter which would clearly indicate fecal contamination from humans may markedly change the assessment of swimmability. This issue is beyond the scope of any remedial action plans, but should be considered for developing a dynamic plan.

3.8 References

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4.0 BENEFIT/COST FRAMEWORK

4.1 Introduction

4.1.1 - General

This report describes the results of the work undertaken in connection with Phase 4 of the Assessment of the proposed Remedial Action Plans for Hamilton Harbour. The purpose of the report is to assess the economic consequences of various measures which would have the effect of improving or enhancing water conditions in the Harbour. This assessment is based on data generated in the Phases 2 and 3 reports.

As described in the Phase 3 report, there are a number of mitigative and remedial measures which will result in cleaner water or enhanced conditions in Hamilton Harbour. Selection of the appropriate control measure or group of measures depends, among other things, on the end-uses which are desired for the Harbour. This study focuses on sportfishing as a primary goal of improved water quality. With this focus in mind, the Phase 3 report identified nine control measures which would be cost-effective in promoting recreational fishing.

In the Phase 2 report, estimates were made of the types and amounts of new recreational activity which would be associated with the sequential implementation of the nine control measures. The purpose of this report is to provide a framework for valuing the benefits associated with this new recreational activity, and with improvements in water quality in general, and to provide an indication of the size of these values.

Two different approaches were used to assess the effects of the nine control measures:

- analysis of economic value
- analysis of economic impact.

These approaches are described in detail in Appendix G.

The first approach attempts to measure the change in "welfare" or economic value benefits to residents of the Regional Municipality of Hamilton-Wentworth and the City of Burlington (the "target area") as a result of implementing the control measures, and to compare these benefits to the costs incurred. This change in welfare arises from increased or enhanced recreational opportunities and from simply knowing that the water is cleaner. It should be noted that economic value will occrue, as well, to individuals outside the target area; however, measurement of benefits for the purposes of this study has been restricted to the Hamilton-Burlington area.

The second approach measures the economic impact of the proposals by analysing the direct and indirect expenditures made as a result of implementing the control measures and improving conditions in the Harbour, and estimating the associated increases in income and employment which accrue to residents of the target area.

Both approaches are relevant in assessing the desirability of investment in control measures. In addition, assessment of economic value provides the basis upon which to choose between alternate measures so as to maximize economic efficiency.

The bulk of the study concerns the estimation of economic benefits. Thus, a brief description of their measurement, and of the concept of benefit-cost analysis, is provided below. A detailed description of benefit-cost analysis is contained in Appendix H.

4.1.2 - Measurement of Economic Value and the Concept of Benefit-Cost Analysis

Investment in measures to control water conditions in the Harbour will give rise to "goods" in the form of cleaner water and any activities which are made possible or which are enhanced by the change in conditions. The economic value of these goods is the difference between the full value of the good or activity (the maximum price or amount of expenditures that individuals would pay for the good or activity) and the price or expenditures actually incurred by these individuals in "consuming" the good or participating in the activity. The value of this difference is termed "consumer surplus" or "net willingness to pay". It is this measurement of value which is consistent with the concept of "benefit" in benefit-cost analysis.

In a benefit-cost analysis, both benefits and costs must be valued at their opportunity costs, often by reference to market prices. This is the case when valuing the cost of the proposed control measures. However, the "good" which is produced by controlling conditions in Hamilton Harbour is cleaner water. Since water is not traded on a market, there is no price attached to it, although it is clear that people place a value on clean water. Specifically, the studies which have been done to evaluate changes in water quality have, collectively, identified the following types of economic benefits associated with changes in water quality.

- "Use Value" - that is the increase in welfare to people who actually "use" the water, for example, for sportfishing or swimming.
- "Non-use" or "intrinsic" value which arises simply from knowing that the water is cleaner and that they could participate in enhanced recreational opportunities as a result. Intrinsic value is sometimes further subdivided into:
    - Option value - an "insurance" value attached to preservation or creation of the option to use the resource in the future.
    - Existance value - the value placed on knowing that conditions have been preserved or improved.
    - Bequest value - the value placed on being able to pass on to future generations better environmental conditions.

Ideally, estimation of these values should be based on a survey of residents in the target area to determine their "willingness to pay" for certain recreational opportunities and for given levels of water quality in the Harbour. However, the budget and time available precluded primary data-gathering. Instead, estimates of economic benefits have been derived from studies of other water bodies, both in Canada and the U.S. Judgement has been applied to these results to adjust for differences between circumstances in the areas studied and those in Hamilton Harbour. The resulting estimates of economic value are not precise but provide reasonable "order-of-magnitude" estimates of these benefits.

Lack of data has limited the estimation of benefits in other ways as well. Calculation of use value in this study has been restricted to new sport fishing and swimming opportunities. Although an increase might be expected in recreational boating as a result of improved conditions in the Harbour, this activity is currently limited by access constraints and, thus, no increase in use can be assumed. Increased participation in and enjoyment of various current activities and the development of new activities, are likely to take place as well; however, no data is available upon which to base estimates of economic value.

In addition, the estimation of economic benefits has been based on patterns of use of Hamilton Harbour which are either existing or foreseeable over the short-term. These patterns of use and the associated economic value are likely to change over the medium- to long-term as constraints to use (such as boating access) are removed and as people become more aware and confident of the improved water quality in the Harbour.

Finally, it should be noted that benefit-cost analysis is a very complex process, particularly in a non-traditional application. Due to limited data and resources, the current study constitutes a benefit-cost "framework" or "assessment" rather than a benefit-cost analysis per se. The results should therefore be interpreted as indicative rather than conclusive.

4.2 Results of Benefit-Cost Assessment

4.2.1 - Introduction

As described in the Phase 3 Report, there are a number of mitigative and remedial measures which will result in cleaner water or enhanced conditions in Hamilton Harbour. Selection of the appropriate control measure or measures depends, among other things, on their relative cost-effectiveness in achieving certain levels of abatement (as described in Appendix H) and on the desired end-uses of the Harbour.

In this section we:

- provide a brief description of the process which led to the sequence of control measures chosen for the benefit-cost assessment;
- list these measures and their costs;
- describe their effects on activities in the Harbour;
- calculate the values associated with these effects; and
- compare the costs and benefits.

It should be noted that the costs and benefits reported in this study represent the amounts of each (in constant 1987 dollars) that can be expected in a typical year following implementation of the control measure(s). Multiplying these amounts by 13.5

will convert them into net present value terms. A fuller description of this approach is provided in Appendix H.

4.2.2 - Proposed Control Measures and Costs

End-uses for Hamilton Harbour which were identified by the stakeholders include swimming and water sports, enhanced recreational fishing and boating, and an improved wildlife habitat and education resource, as well as continued use of the Harbour for shipping and navigation, industrial water supply, and a waste water receiving body. The current study focuses on a self-sustaining, warm-water recreational fishery as a primary goal and benefit of improved water quality in Hamilton Harbour. Recreational fishing was chosen as a popular activity the quality of which reflects the quality of water in general. In particular, Northern Pike and Large Mouth Bass were identified as representative species for this fishery.

With these requirements in mind, the Phase 3 report identified restorative and remedial measures which will have the effect of increasing the yield of Northern Pike and Large Mouth Bass in the Harbour. It is assumed that the presence of a preferred species and the increase in the "catch per unit of effort" will stimulate new fishing activity. Nine measures were identified which would substantially increase the yield of Northern Pike and Large Mouth Bass in Hamilton Harbour. These measures, and the costs of each, are shown in Table 4-1.

TABLE 4-1

ESTIMATES OF COSTS OF PROPOSED CONTROL MEASURES (in 000's of 1987 dollars/year)

Control Measure		Cumulative Cost
1.	Enhance Grindstone Upper	$ 17
2.	Enhance Cootes Paradise	139
3.	Grindstone Delta	163
4.	North Shore Burlington	176
5.	Lax Property	232
6.	Perimeter Road	328
6 Prime	Effect of Light on Measures 1 - 6	328
7.	Sand Filters in STP	6,500
8.	CSO Control	12,200*

Source: Phase 3 report.

The control measures are described in detail in Appendix I. Briefly, measures 1 through 6 Prime constitute restorative or mitigative measures - that is, activities that will enhance the use of the Harbour but not necessarily reduce pollution. Measures 7 and 8 represent groups of remedial measures - that is activities which will reduce pollution at a specific source. These two groups of remedial measures were chosen for evaluation in the Phase 3 analysis because they represent points in the cost-effectiveness curve for adult fish habitat where substantive improvements in light penetration, and therefore fish yield, result. As noted in the Phase 3 report, the restorative measures are much more cost-effective than the remedial measures in creating a self-sustaining, warm-water fishery. This is because spawning and hatching areas in the Harbour are currently so limited that they create a greater obstacle to fisheries development than does water quality.

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* *Increases to $12.8 million assuming implementation of additional measures described on page 4-8.*

The annual costs in Table 4-1 are "cumulative" - that is, they are calculated on the assumption that the measures are implemented sequentially in the order shown. The costs are stated in 1987 dollars and represent the cost of capital, amortized over a 20-year period, plus operating and maintenance costs in a typical year following implementation of the measures concerned.

4.2.3 - Effects of the Control Measures and Approaches for Valuing

Implementation of the control measures identified in Table 4-1 will result in an increase in fishing activity, as intended. However, the resulting water conditions affect other activities as well and, in addition, provide intangible benefits. The increases in recreational and educational activities which are expected as a result of the control measures are shown in Table 4-2. (Because the measures proposed are not expected to infringe on any current activities in the Harbour, such as shipping, it has been assumed that there are no disbenefits associated with their implementation.)

TABLE 4-2

CURRENT AND FUTURE RECREATIONAL AND EDUCATIONAL ACTIVITY IN HAMILTON HARBOUR

Activity	Current Use (User-days)	Increases in Use Due to Control Measures	Comments
Recreational Fishing	5,000	See Table 4-3.	
Recreational Boating	80,000	No increase.	Future increases in boating will be due to waterfront development.
Outdoor Education and Nature Interpretation	65,000	Not known.	
Board Sailing	Minimal	Included in swimming estimate.	
Swimming	Nil	1.1 million user-days.	Assumes implementation of all nine control measures, beach development, and curtains/disinfection.

Source: Phase 2 report

It is estimated that there will be no increase in recreational boating activity as a result of the control measures, although there will be an increase (of approximately 37,000 user-days) due to waterfront development. This waterfront development is not connected with any of the measures listed in Table 4-1 and, therefore, benefits resulting from an increase in boating have not been included in the current analysis. No estimate is possible of the increase in outdoor education and nature interpretation activities which is due specifically to the remedial and mitigative measures. Programs and the number of participants in these programs are thought to be currently more limited by funding than by water quality. No swimming activity is projected until the implementation of control measure 8; at this point, water quality is improved to the point that swimming is possible. Levels of activity, however, depend on additions to beach area in the Harbour as follows:

- 425-metre beach at Hamilton Island Lagoon;
- two 500-metre beaches at Burlington Beach;
- 100-metre beach at Lasalle Park.

It is also recommended as an additional safeguard to water quality, that curtains be installed around the beach areas and that disinfection be undertaken within the curtains. (See section 3.7). The costs associated with beach developments and curtains/disinfection are not included in the figures in Table 4-1. Assuming they are undertaken in conjunction with implementation of all nine control measures, the total cost associated with measures 1 through 8 rises from $12.2 million (as shown in Table 4-1) to approximately $12.8 million per year (in 1987 dollars). (This assumes the mid-point of the range of operating and maintenance costs estimated for curtains/disinfection in Section 3.7).

The estimated increments in fishing activity for the sequence of control measures are presented in Table 4-3. Estimates of potential angler-days represent incremental levels of activity over and above the current estimated usage of 5,000 user-days. These estimates do not represent total potential interest in fishing by Hamilton-area residents. They are derived directly from estimates of yield of Northern Pike and Large Mouth Bass and represent the maximum fishing activity which can be supported by the quantity of these fish available. The number of angler-days has not been adjusted to take into account the possibility that other species may be enhanced or endangered by the control measures.

TABLE 4-3

ESTIMATES OF NEW FISHING ACTIVITY FROM PROPOSED CONTROL MEASURES

Control Measure		Cumulative New Angler Days/Year
1.	Enhance Grindstone Upper	-
2.	Enhance Cootes Paradise	2,700
3.	Grindstone Delta	2,750
4.	North Shore Burlington	4,000
5.	Lax Property	4,000
6.	Perimeter Road	4,000
6 Prime	Effect of Light on Measures 1 - 6	5,300
7.	Sand Filters in STP	5,550
8.	CSO Control	5,650

Source: Phase 2 report. Numbers shown are the mid-point of the range of potential angler days estimated in the Phase 2 report.

In summary, the proposed control measures result in:

- increased fishing activity for all measures; and
- significant swimming activity after implementation of control measure 8 and assuming expansion of beach area.

Boating activity in the Harbour is currently constrained by lack of facilities and access, and therefore no increase is projected as a result of water quality improvements. However, the implementation of control measures 7 and 8 and the resulting improvement in water quality may result in a more enjoyable "boating experience" and therefore increased economic value. Similarly, anglers who currently fish in Hamilton Harbour may enjoy it more after the measures are implemented. Benefits accruing to residents from all these activities are reflected in increased use values. Cleaner water also gives rise to benefits in itself - as reflected in option, existence, and bequest values associated with the level of water quality improvement achieved. The values which may be attached to these benefits are discussed below.

4.2.4 - Value of Benefits

The benefits from cleaner water in Hamilton Harbour arise in two distinct ways:

- Increased use values due to new activity generated by improved water conditions and by increased enjoyment of current activities, and
- Non-use values associated with better water conditions in general.

Use Values

Annual use values accruing to residents of the Hamilton-Burlington area from new fishing and swimming activity and enhanced fishing and boating can be defined conceptually as:

- for new fishing and swimming activity:
    - average consumer surplus per fishing day times the number of new angler-days per year
    - average consumer surplus per swimming day times the number of new swimming days per year.
- for enhanced fishing and boating:
    - the increase in consumer surplus per fishing day times the current number of angler-days per year, plus
    - the increase in consumer surplus per boating day times the current number of boating days per year.

In order that the results for new activity accurately represent the increased use value to the residents of the area, two conditions must be met. First, the new swimming and fishing activity must be undertaken by residents of the Regional Municipality of Hamilton-Wentworth and the City of Burlington and not from neighbouring locations. This is believed to be a reasonable assumption given the availability of fishing and swimming opportunities outside Hamilton Harbour.

Secondly, all of the fishing and swimming days valued must represent new activity as opposed to activity which has been diverted to Hamilton Harbour from other locations. For example, residents who currently fish in the Muskokas and who decide, after implementation of the control measures, to fish in Hamilton Harbour instead, represent diverted activity. For diverted activity, the estimate of consumer surplus should be adjusted, for example, for the difference in the travel cost incurred by fishing or swimming in Hamilton Harbour versus the former location. However, no details are available regarding the proportion of increased activity which is diverted or, furthermore, the locations from which such activity is being diverted. Thus, estimates of increased value are made on the assumption that all increased activity is new and, as such, may overstate the increase in consumer surplus.

As described in Appendix H, estimates of consumer surplus for a nonmarket-traded good or activity such as fishing can be derived in a number of ways. Generally, studies estimating consumer surplus incorporate a complex set of assumptions and descriptions which are largely specific to the sites being studied and to the population of the associated target area. For this reason, it is preferable that primary data be gathered as a basis for estimating the current economic value of recreational fishing in Hamilton Harbour and willingness to pay for a particular change in conditions at the site in question. However, the timeframe and budget for this study was such that a primary survey was not possible. Thus, estimates of average consumer surplus per day for fishing and swimming have been derived from a survey of studies conducted in the United States and in Canada.

Use Value From New Fishing Activity

Estimates of consumer surplus associated with recreational fishing are presented in Table 4-4. A more detailed description of these estimates and the studies from which they were derived is contained in Appendix J. The estimates contained in this Table were derived using either a direct survey approach or travel cost method. All of the results have been converted into 1987 Canadian dollars. Most are directed at valuing a user-day of recreational fishing, (with the implicit assumption that the alternative is no fishing at the site) rather than assessing the value of a change in the quality of fishing. They are therefore roughly applicable to estimates of new fishing activity in Hamilton Harbour.

TABLE 4-4

ESTIMATES OF CONSUMER SURPLUS ASSOCIATED WITH RECREATIONAL FISHING (USE VALUE)

(in 1987 Canadian Dollars)

Activity Being Valued	Location	Consumer Surplus per Fishing Day	Year of Study
Recreational Fishing	6 Ontario lakes	$11	1985
Salmon Fishing	Victoria, B.C.	24	1984
	Campbell River, B.C.	40	
	Sechelt, B.C.	47	
	Port Alberni, B.C.	83	
	Campbell River Guided	95	
Recreational Fishing	Alberta	31	1976
Recreational Fishing	Haliburton/Muskoka Region, Ontario	23	1983
Angling	Lake of the Woods, Ontario	6	1982
Trout Fishing	Fee-fishing sites, U.S.A	33	1979
Catfish Fishing	Fee-fishing sites, U.S.A	21	
Fishing	Adirondacks, N.Y	43	1976
Fishing	Snake River, Idaho	25	1983

Source: See Appendix J.

Based on the results of these studies, the economic value of one day of fishing is somewhere between $6 and $40. (The higher estimates included in the Table - of $95, $83, $47 and $43 - have been eliminated from this range since it is likely that they represent exceptional fishing conditions which are not comparable to those which will exist in Hamilton Harbour.) The mid-point of this range is $23 per fishing day. Applying this number to the number of new fishing days estimated in Table 4-3, results in the total use value from new fishing activity shown in Table 4-5.

TABLE 4-5

USE VALUE FROM NEW RECREATIONAL FISHING ACTIVITY IN HAMILTON HARBOUR
(1987 dollars/year)

Control Measure		Cumulative Use Value
1.	Enhance Grindstone Upper	n/a
2.	Enhance Cootes Paradise	$ 62,000
3.	Grindstone Delta	63,000
4.	North Shore Burlington	92,000
5.	Lax Property	92,000
6.	Perimeter Road	92,000
6.Prime	Effect of Light on Measures 1 - 6	122,000
7.	Sand Filters in STP	128,000
8.	CSO Control	130,000

Source: Tables 4-3 and 4-4.

It is likely that most of the estimates in Table 4-4 apply to situations in which the fish caught are edible. Most of the control measures proposed here will not create conditions under which fish would be edible, according to provincial standards. However, it is not clear how much the estimates of consumer surplus will vary according to edibility or non- edibility of the fish caught. For this reason, no attempt has been made to adjust the results.

Use Value From New Swimming Activity

Swimming becomes possible in Hamilton Harbour after the implementation of all the control measures listed in Table 4-1. At this point, the water is clean enough that swimming, with additional safeguards in the form of curtains and disinfection, is safe. It is assumed, for the purposes of this study, that swimming takes place only at safe locations.

The estimate of swimming activity which is generated by implementing all nine control measures is approximately 1.1 million user-days per year. As noted earlier, this estimate assumes the development of four beaches in the Harbour. To translate this activity into an estimate of use value, it is first necessary to determine the consumer surplus associated with swimming.

Studies which estimate the consumer surplus associated with swimming are less readily available than those for fishing. One study uses the travel cost method to estimate the economic value of one "home based" swimming occasion at approximately $5 (in 1987 dollars) (reference #18). This estimate assumes an average round-trip time of approximately one-half hour. Another study uses an estimate of just over $5 per day (in 1987 dollars), although it is not clear how this number is derived (reference #17). Based on consumer surplus from swimming of $5 per day, the total use value accruing to residents of Hamilton-Wentworth and the City of Burlington from swimming activity is approximately $5.5 million per year. This figure represents an upper bound since part of the swimming activity may be diverted from other locations and a small portion may be generated by residents from outside the Hamilton-Wentworth/Burlington area.

Use Value From Enhanced Boating and Fishing By Current Users

Although there is no projected increase in boating activity as a result of the proposed control measures, there may be increased enjoyment of current activity as a result of the improved water conditions. However, there is very little data available on the extent to which consumer surplus from boating would change as a result of improvements in water quality, however defined. One study links a change in consumer surplus for boating with changes in chlorophyll a concentrations (reference #17). The latter are used as a proxy for plant growth in the water. However, calculation of the change in chlorophyll a concentrations was not included as part of the Phase 3 report and, thus, we have no basis for estimating the change which would occur in economic value as a result of enhanced boating in Hamilton Harbour.

Similarly, the increased fish yield and presence of preferred species in the Harbour as a result of the control measures can be expected to yield increased enjoyment of fishing by the current users. However, appropriate data are not available upon which to make an estimate of the resulting increase in economic value. For the same reason, estimates are not attempted of the increase in enjoyment from outdoor education and nature interpretation, nor of increases in other new or current activities.

In summary, no estimate can be made of use value from increased enjoyment of current recreational and educational activities in Hamilton Harbour. However, this benefit is likely to be small. For example, assuming that the average consumer surplus for boating, fishing and outdoor education is $10 per user-day and that implementation of the control measures increases this value by 10%, the incremental use value to current boaters, anglers and other users - for total use of 150,000 user days, as estimated in Table 4-2 - is $150,000. This is a small amount relative to the use value associated with swimming activity.

Non-Use Values

Non-use or "intrinsic" values are those which individuals place on improving (or preventing deterioration in) environmental quality but which have nothing to do with current use of the resources affected. A number of studies have been done, primarily in the U.S. but also in Canada, which attempt to quantify these values, following a number of different approaches. Some studies attempt to estimate a total willingness to pay for environmental improvements, thus including in the estimate both use and non-use elements (reference #14). Others distinguish between use and non-use values, providing separate estimates for each (reference #25). Recently, some studies in the U.S. have identified components of intrinsic values - including option, existence, and bequest values described in Section 4.1.2 - and have attempted to place a value on each of these components (references #5 and #25).

In the studies reviewed for this report, estimates of non-use value were generally based on surveys of individuals' willingness to pay for given changes in either water quality or aspects of wilderness resources. The improvements may be related to one specific site or a group of sites, or may be national in scope. In any case, the benefits are assumed to accrue to all residents of the geographic area under study and are therefore generally estimated per household per year.

Changes in water quality are often described in terms of pollution-related measures such as metallic content (reference #5) or by reference to a "water quality ladder" (references #14 and #25). These water quality ladders describe the water in terms of the activities which are possible at different quality levels or in terms of the eco-system, and particularly the fish habitat, that the water could support. However, although the availability of fish for fishing is a prominent descriptor in these ladders it is implicitly assumed that the quality of fishing is dependent on the quality of the water. The resulting estimates of non-use values in these studies are therefore applicable to changes in water quality rather than to recreational activities such as fishing. Although there may be intrinsic value associated with the ability to fish in itself, there are no data upon which to estimate it.

The first seven control measures proposed for Hamilton Harbour are mitigative only. Although they result in improved fishing in Hamilton Harbour, they do not reduce pollution in the water. Thus, they represent an anomaly in the context of the studies cited above, which link changes in fishing to changes in water quality. For this reason, the intrinsic value associated with measures 1 through 6 Prime is assumed to be zero.

The literature has a wide range of estimates for intrinsic values associated with cleaner water. This is due to:

- Differences in methodology among different studies;
- Differences in the size and characteristics of the water- bodies concerned;
- Differences in the magnitude of the proposed changes in water quality and the ways in which these quality changes are described;
- Alternatives, available to the individuals being surveyed, with respect to water-based recreation, the distance that must be travelled to get to cleaner lakes or rivers which offer these opportunities, etc.
- Whether a value is being placed on improving water conditions or preventing their deterioration.

It is not possible to standardize the data available in the literature so that estimates of use and non-use components are fully comparable. However, based on the information available, we have derived the following estimates of non-use values:

- For an improvement in water quality from "boatable" to "fishable" - $87 to $146 per household per year (1987 $);
- For an improvement in water quality from "boatable" to "swimmable" - $103 to $153 per household per year (1987 $).

The basis for these calculations is described in Appendix K. Based on these results, it appears reasonable to assume that the non-use value associated with improving the water in Hamilton Harbour to the level suggested by measure 8 - that is, swimmable - is in the order of $100 per household per year. Based on 1986 data, there are approximately 196,000 households in the Regional Municipality of Hamilton-Wentworth and the City of Burlington. Thus, total intrinsic value accruing to the area from implementation of all nine control measures is approximately $19.6 million.

It is unclear what the appropriate non-use value is to apply to measure 7. This measure reduces pollution in the Harbour but not as much as measure 8. Although the water is "fishable" at this level (as it is for measures 2 through 6 Prime), it is not known whether it is of a quality equal to that implied by the term "fishable" as used in the literature. As noted earlier, although a number of studies estimate the non-use value of improving water quality to a "fishable" level, the implication in these studies is that achieving this requires a substantial improvement in water quality. However, no explicit measurement is offered of the degree of water quality change involved. One study (reference #5) describes water quality changes in terms of a physical parameter but the parameter used - metallic content - is different from the measurement of water quality used in the current study. In the absence of better information, therefore, it has been decided to assume a non-use value of zero for measure 7. The effect of assuming a positive non-use value for this measure is addressed in the next section.

4.2.5 - Benefits Versus Costs

Total Economic Value

The total economic value associated with the sequence of proposed control measures is shown in Table 4-6. The estimates in this table include use value arising from new fishing and swimming activity and intrinsic value associated with improvements in water quality in the Harbour. Some major assumptions upon which these figures are based are as follows:

- Use values have not been adjusted downward to reflect fishing and swimming activity diverted by residents of the Hamilton-Wentworth/Burlington area from other locations to Hamilton Harbour.

TABLE 4-6

TOTAL ECONOMIC VALUE FROM CONTROL MEASURES
(000's of 1987 dollars/year)

Control Measure		Cumulative Use Value*		Cumulative Non-Use Value	Total Economic Value
		Fishing	Swimming		
1.	Enhance Grindstone Upper	-	-	-	-
2.	Enhance Cootes Paradise	$ 62	-	-	$ 62
3.	Grindstone Delta	63	-	-	63
4.	North Shore Burlington	92	-	-	92
5.	Lax Property	92	-	-	92
6.	Perimeter Road	92	-	-	92
6 Prime	Effect of Light on Measures 1 - 6	122	-	-	122
7.	Sand Filters in STP	128	-	-	128
8.	CSO Control	130	$5,500	$19,600	25,230

* Does not include use value from enhanced boating, fishing and outdoor education by current users.

Source: Table 4-5; see text.

- No use values have been estimated to reflect increased enjoyment of boating, fishing and other recreational and educational activities by current users of the Harbour.
- No use values have been estimated for new activities other than fishing or swimming.
- Intrinsic value has been assumed to be zero until all nine control measures have been implemented. At this point, a value of $100 per household per year is assumed.

No conclusions have been drawn regarding the distribution of economic value across different income groups and geographic areas witin the Hamilton-Burlington region. Presumably some individuals in the target area will benefit more from the improvement in Harbour conditions than others will. For example, individuals who currently have access to fishing and swimming elsewhere may benefit less from improved water quality than will those who have no alternatives. As another example, home-owners living close to the Harbour may see a greater increase in property value than those further away. These distributional effects have not been evaluated.

Net Benefits

The annual net benefits arising from the sequence of control measures are shown in Table 4-7. According to these estimates, benefits exceed costs only after implementation of measure 8. At this level, the net benefits amount to $12.4 million per year.

The estimation of net benefits is highly dependent on assumptions regarding intrinsic values. The results in Table 4-7 assume a non-use value of $100 per household per year, after implementation of measure 8. As noted earlier, this figure is based on the results of a number of studies which derived non-use values for preserving or improving water quality in various locations in Canada and the U.S. Without conducting a survey of Hamilton-area residents, this is the only basis available to estimate the intrinsic value associated with improving water conditions in Hamilton Harbour. However, it is not clear that non-use values derived for one set of areas and circumstances are transferrable to another location and situation. The analysis which follows, therefore, addresses the issue of intrinsic values from another perspective - by calculating the

TABLE 4-7

NET BENEFITS ASSOCIATED WITH CONTROL MEASURES (000's of 1987 dollars/year)

Control Measure		Cumulative Benefits	Cumulative Costs	Net Benefits	Benefit-Cost Ratio
1.	Enhance Grindstone Upper	-	$ 17	$ (17)	-
2.	Enhance Cootes Paradise	$ 62	139	(77)	0.45
3.	Grindstone Delta	63	163	(100)	0.39
4.	North Shore Burlington	92	176	(84)	0.52
5.	Lax Property	92	232	(140)	0.40
6.	Perimeter Road	92	328	(236)	0.28
6 Prime	Effect of Light on Measures 1 - 6	122	328	(206)	0.37
7.	Sand Filters in STP	128	6,500	(6,370)	0.02
8.	CSO Control	25,230	12,800*	12,430	2.00

* Includes cost of beach development, installation of curtains and disinfection.

Source: Table 4-1 and 4-6

values which result in positive net benefits and assessing the reasonableness of these values.

Net benefits associated with implementation of all nine control measures are $12.4 million per year assuming a non-use value of $100 per household per year. Intrinsic values do not have to be nearly this high in order to result in positive net benefits. Because of the high use value associated with swimming activity brought about by measure 8, a non-use value of approximately $37 annually per household would result in equal costs and benefits for this measure. (This figure may be adjusted once the cost of beach development is known.)

Net benefits for measures 1 through 7 assume a non-use value of zero. In fact, there may be intrinsic value associated with improved fishing conditions in Hamilton Harbour at the same level of water quality - as is the case for measures 1 through 6 Prime. However, there is no basis in the literature for estimating this value. Measure 7, on the other hand, reduces pollution in the Harbour; some intrinsic value will therefore be attached to the resulting improvement in water quality. If a non-use value of $33 annually per household were assumed, for example, the resulting benefits would slightly exceed costs. How reasonable this estimate is depends on the non-use value assumed for implementation of all nine control measures; in the latter case, the resulting improvements in water quality and, therefore, non-use values, are considerably greater.

In themselves, however, the estimates of non-use value necessary to "break even" after implementation of measures 7 and 8 - of $33 and $37 per household per year, respectively - are not unreasonable given the results of the studies reviewed, as described in Appendix K.

It is not suggested that the estimates of benefits in Table 4-7 are precise. Estimates of consumer surplus and the intangible benefits associated with environmental improvements can not be made with any precision, even when they are based on primary data. However, the literature review suggests that there are significant use and non-use values associated with improved water quality and recreational opportunities. Therefore, while the results shown in the Table may not be exact, they provide an indication of the control measures which will result in net economic benefits, and the order of magnitude of these benefits. A sensitivity analysis to determine how these results change, given variations in some of the key underlying assumptions, is contained in the Phase 5 report.

As described in Section 4.1.1, the net benefits reported above reflect the change in economic welfare accruing to residents of the Hamilton area as a result if implementing the control measures. An alternate way of assessing the economic consequences, and a potential additional offset to the costs of the control measures, are the economic impacts associated with implementing the measures. These are discussed below.

4.3 Economic Impacts

4.3.1 - Introduction

This Chapter assesses the economic impacts associated with implementation of the sequence of control measures identified in Section 4.2 (Economic impact analysis is described in Appendix G). Economic impacts are assessed in terms of the increased employment and income accruing to residents of the target area - that is, the Regional Municipality of Hamilton-Wentworth and the City of Burlington - as a result of expenditures made in connection with improving water quality in Hamilton Harbour.

Theoretically, economic impacts will arise from two different sets of expenditures:

- Direct expenditures on materials and labour used in the implementation of the control measures.
- Expenditures arising from increased recreational activity in the Harbour as a result of improved water conditions.

These are discussed separately below.

4.3.2 - Impact of Expenditures Incurred in Implementing Control Measures

A breakdown of capital and operating and maintenance costs for the proposed sequence of control measures is contained in Table 4-8. These figures are derived from the Phase 3 report and are the basis for the cost estimates shown in Table 4-1.

Costs in Table 4-1, however, amortize capital expenditures over a twenty-year period - a period reflecting the "life" of the capital equipment. Allocating costs in this manner

TABLE 4-8

ESTIMATED CAPITAL, OPERATING AND MAINTENANCE COSTS OF PROPOSED CONTROL MEASURES
(1987 dollars)

Control Measure		Cumulative Costs	
		Capital ($ millions)	Operating and Maintenance ($ thousands/ year)
1.	Enhance Grindstone Upper	$ 0.10	$ 10
2.	Enhance Cootes Paradise	1.10	60
3.	Grindstone Delta	1.30	70
4.	North Shore Burlington	1.42	75
5.	Lax Property	1.92	95
6.	Perimeter Road	3.12	105
6 Prime	Effect of Light on Measures 1 - 6	3.12	105
7.	Sand Filters in STP	60.22	2,185
8.	CSO Control	131.87*	3,345*

* Includes cost of beach developments, and curtains/disinfection.
Source: Phase 3 report.

is appropriate when the goal is to compare the costs with the benefits arising from the investment. However, economic impacts are generated at the time expenditures are made. The impacts are therefore different for capital expenditures - which are "one-time" costs - and for operating and maintenance costs which are incurred annually over the twenty-year period.

As noted in Appendix G, not all of the expenditures made in implementing the measures will be retained in the Hamilton-Wentworth/Burlington area. Some of them will be made on goods and labour from other parts of the province or Canada or on imports. Given the small size of the target area it is likely that a significant portion of the initial expenditures will be made outside the area, although these may be compensated for, to some extent, by indirect and induced expenditures which are retained within the Hamilton-Wentworth/Burlington area.

Based on an income multiplier for nonresidential construction of 0.9 and on the creation of 10.0 person-years of employment per $1,000,000 of direct expenditure*, the final results in terms of added income and employment accruing to residents of Hamilton-Wentworth/ Burlington are shown in Table 4-9.

The capital costs of implementing the first seven measures (that is, measures 1 through 6 prime) in the sequence of proposed control options result in added income in the target area of just under $3 million and in the creation of approximately 30 person-years of employment. After the measures are in place, operating and maintenance expenditures will result in just under $100,000 increased income per year. Very few jobs are created on an annual basis.

The impact of implementing all nine control options is much greater. Capital construction gives rise to $120 million of income during the construction phase and $3 million per year thereafter. Thirteen hundred person-years of employment are created during the implementation phase and 30 per year thereafter.

In summary, the economic impact of implementing measures 1 through 6 Prime is insignificant. This is not surprising given the investment required for these measures. Impacts from the total program of control options are sizeable during the capital construction phase but small thereafter.

4.3.3 - Impact Arising From Expenditures on Increased Recreational Activity

Improvement of water conditions in the Harbour are projected to result in increased recreational fishing and in swimming. A certain amount of income and employment will be generated by expenditures on these activities. However, these effects are likely to be quite small given the low initial expenditures associated with swimming and local fishing efforts.

Economic Impact of New Recreational Fishing

Estimates of average expenditures per angler are available from a number of sources (see references #17, #20 and #29). These sources suggest that expenditures by fishermen will not exceed $100 per angler. This includes fishing services, fishing gear, and purchases of "major" fishing equipment. It does not include expenditures on boats;

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* *These figures are derived from Statistics Canada's input-output analysis.*

TABLE 4-9

INCOME AND EMPLOYMENT IMPACTS IN HAMILTON/BURLINGTON FROM CONTROL MEASURE EXPENDITURES

	From Implementation of:	
	Measures 1-6 Prime	Measures 1-8
INCOME ($ 1987)		
Construction Phase ($ millions)	$3.0	$ 120.0
Post-construction ($millions/year)	$0.1	$3.0
EMPLOYMENT		
Construction Phase (person-years)	30	1,300
Post-construction (annual person-years)	Small	30

Source: See text.

however, it is likely that much of the fishing activity will be undertaken from the shore or from piers. Without information regarding the nature of the fishing generated in Hamilton Harbour, it is not possible to assess the reasonableness of this estimate for this study. However, it is likely that expenditures of $100 per angler in the Hamilton area constitute an upper bound and, therefore, provides the basis for estimating the maximum economic impact which can be expected from increased fishing activity.

The highest estimate of increased fishing activity in Hamilton Harbour is 5,650 angler-days per year associated with the implementation of all nine control measures. (See Table 4-3). This figure is constrained by the availabilty of fish and is not based on the potential number of anglers or angler-days. One study (reference #11) esimates that the average angler fishes approximately 16 times per year. This figure is probably too high for Hamilton Harbour. Using an arbitary estimate of 5 fishing days per angler, the estimate of 5650 angler-days translates into approximately 1100 anglers. Assuming average expenditures per angler are $100, the total direct expenditures made in connection with new fishing activity will be in the order of $110,000. This amount may be increased if there are significant increases in boat purchases.

Expenditures of $110,000 related to new fishing activity will result in the following effects within the Hamilton-Wentworth and Burlington area:

- Increased income of $110,000 per year.
- Creation of 4 person-years of employment annually.

These estimates assume an income multiplier of 1.0 and that 35 person-years of employment are generated for every $1,000,,000 of recreational expenditure.*

Economic Impact of Recreational Swimming

Assuming implementation of all the proposed control measures, development of four additional beaches and investment in curtains and disinfection as described in Section 4.2.3, swimming activity in Hamilton Harbour will amount to approximately 1.1 million user-days. We have no data on average expenditures per swimmer although it is reasonable to assume that they will be very small. Assuming, for the purposes of illustration, that each swimmer spends an average of $2.00 per day - primarily for transportation, food and drinks which he would not otherwise buy - total direct expenditures arising from the swiming activity will be in the order of $2 million.

Using the multipliers for sportsfishing above, these expenditures result in the following economic impacts within the targert area:

- Increased income of $2 million per year.
- Creation of 70 person-years of employment annually.

Summary of Economic Impact of Increased Recreational Activity

Expenditures associated with increased sportfishing and swimming after implementation of all nine control measures will result in additional income to the Hamilton area of approximately $2 million per year and some 75 person-years of additional employment per year. These effects are comparable to the economic

These multipliers are based on estimates by the Ontario Ministry of Tourism and Recreation (reference #21) but have been judgementally adjusted to reflect the smaller size in the area under study relative to the areas for which the MInistry derived its multipliers.

impact of operating and maintenance expenditures associated with the same control measures and described in Table 4-9. Both sets of impacts are small.

4.4 Key Findings

The analysis in this study is based on estimates, contained in the Phase 2 report, of increased activity as a result of improving water conditions in Hamilton Harbour. Specifically, it is estimated that 5,650 new angler-days and 1.1 million swimming days per year will be generated by the nine control measures proposed in the Phase 3 report. Based on these results, the key findings of this study are as follows:

- New recreational activity and improved water quality result in economic value within the Regional Municipality of Hamilton-Wentworth and the City of Burlington in the following ways:
    - "use value" from increases in fishing and swimming and through increased enjoyment by current anglers and boaters
    - "non-use value" from intrinsic benefits to Hamilton-area residents from improved conditions in the Harbour.
- The annual value, in 1987 dollars, of the economic value benefits associated with implementation of all nine control measures is estimated at:
    - $0.13 million from increased fishing activity
    - $5.5 million from swimming activity
    - $19.6 million non-use value.
- Total annual economic value for the sequence of proposed control measures is as follows:
    - $0.13 million from implementation of measures 1-7
    - $25.2 million from implementation of all nine control measures.
- Economic value benefits exceed the associated costs after implementation of measure 8 and possibly after implementation of measure 7. Net benefits in the former case are estimated at $12.4 million per year; the associated benefit-cost ratio is 2.0.

- Estimates of net benefits are highly dependent on estimates of non-use value. The figure used in this study - of $100 per household per year - is based on the results of a number of studies which have estimated non-use values for preserving or improving water quality in various locations in Canada and the U.S. There is some question whether values derived for other areas and circumstances are transferrable. Thus, the results should be interpreted with this qualification in mind.

- **Economic impacts** generated by increased recreational activity as a result of improved conditions in the Harbour are small. Expenditures associated with implementation of the control measures give rise to significant income and employment effects during the construction phase. Construction involved in implementing all nine control measures results in the creation of 1,300 person-years of employment and added income to the Hamilton area of $120 million.

4.5 References

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5.0 SENSITIVITY ANALYSIS

5.1 Introduction

This section highlights significant information gaps that were not adequately addressed in the earlier phases. It addresses the uncertainties and assumptions regarding the linkages between water quality, the proposed uses and benefits. A sensitivity analysis of key economic assessment components is made. Recommendations are made for additional data gathering and further work.

5.2 Information Gaps

The following is a list of areas identified in this study as requiring further data.

5.2.1 - Harbour Uses

There is no existing data on fisheries specific to Hamilton Harbour. The Ontario Angler Survey does not include Hamilton Harbour as a location in their household questionnaire nor has a Creel Census been done on fish or anglers in the Harbour. No other sources of data exist which are specific to Hamilton Harbour.

Present patterns of participation were estimated for recreational boating and outdoor education. These are activities for which there are major physical facilities and/or organized programs for which level of use can be calculated. Several activities, as listed below, are not organized and have no physical facilities. Information on these activities was not available:

- canoeing and kayaking
- boardsailing
- walking and hiking (unorganized outdoor education activities).

Potential future demand was estimated but was based on the most recent surveys: the 1977 Ontario Recreation Survey (ORS) and the 1981 Canada Fitness Survey. As described in the point above, data for several activities was not available at all and existing sources data was not recent.

5.2.2 - Remedial and Mitigative Measures

More detailed information would be required from each existing industrial and municipal wastewater treatment plant for purposes of costing for instance; operating capacity, design capacity, specialized treatment methods employed which can include aeration system and tankage.

The most representative and published data collected for loadings to Hamilton Harbour occurred in 1977. A similar comprehensive compilation of all parameters measured for the 1988-89 period will be an asset.

Additional data will need to be collected on heavy metals, PAH, PCB, other chloro-organics, pesticides, etc. in both the water column and in the sediments.

Additional water quality data from non-point sources such as combined sewer overflows and from agricultural lands will be of value for future work.

Fish data for toxics/contaminants have been gathered, but are unavailable at this point in time, making it difficult to complete the edible portion of the modelling study.

The level of contaminants/toxics in other ecological niches has not been measured in a comprehensive fashion and therefore cannot be used for a comparitive valuation.

There is much on the literature concerning the effect of contaminants/toxics on the ability of fish to survive, their uptake, and their edibility. But the effect of mixtures of these compounds as in Hamilton Harbour, and for the effect of specific compounds is not well understood nor detailed.

5.2.3 - Benefit-Cost Framework

The following describes areas identified during the completion of Phase 4 in which data was lacking. Information with respect to non-use values are discussed first because intrinsic values are the major determinent of net benefits in the case of the fisheries investment for Hamilton Harbour. Lack of information in this area is therefore most important as far as the benefit-cost assessment is concerned.

Non-Use Values

This is a relatively recent area of study and, therefore, there is not a great deal of data available on which to base estimates of non-use values. In particular:

- There appear to be no estimates made of intrinsic value associated with "fishing" in itself. Although some studies estimate non-use values associated with improving water quality from its current state to a "fishable" level, the implicit assumption is always that the ability to fish is gained by improving the quality of the water. This is not the case in Hamilton Harbour, at least through to implementation of measure 6 Prime in Table 3.16 of Section 3. The lack of information on the intrinsic value associated with "fishable" water per se (as opposed to cleaner water) has led us to assume a zero non-use value associated with implementation of measures 1 through 6 Prime. This may slightly underestimate the actual economic benefit attached to implementation measures.

- In some cases, it is not possible to determine what the studies are attempting to measure. For example, as noted above, improvements in water quality are sometimes stated in terms of physical or biological conditions (references #5 and #14) or in terms of activities made possible (reference #25). These activities are presumably possible over a range of water quality levels. For this reason, it is sometimes difficult to assess the degree of change in water quality which is being valued by the study in question.

- Estimation of non-use values is usually done for dramatic changes in water quality. Thus, there was no data available upon which to assess a non-use value for implementation of measures 1 through 7 versus implementation of measures 1 through (See Table 4-1). We have therefore assumed a conservative estimate of zero non-use value for measures 1 through 7. This results in economic benefits which are less than the costs involved. As is discussed in Sections 4.2.5 and 5.5.3, this may represent an under-estimation of economic benefits.

Estimates of New Fishing Activities

The effect of the nine control measures proposed for development of a warm water fishery in the Harbour, on yield of Northern Pike and Largemouth Bass was estimated in the Phase 2 report. However, we have no estimates of how the measures will impact on yield of other species. If they result in an increase in other preferred species as well, fishing days, the associated total use value, and net economic benefits will increase as a consequence.

Use Values

The studies reviewed for this report do not differentiate between use value, or consumer surplus, derived from fishing for edible fish versus non-edible fish. (The fish in Hamilton Harbour would be non-edible, according to provincial standards, through at least measure 6 Prime.) Use of the $23 estimate of consumer surplus per fishing day for all control measures may have resulted in an over-estimation of use value for measures 1 through 6 Prime (or, conversely, an under-estimation for measures 7 and 8).

As noted in Section 5.2.1, estimates could not be made of increases in activities, other than recreational fishing and swimming, as a result of improved water conditions. Thus, although increases can be expected in activities such as hiking, organized outdoor education programs, and so on, it was impossible to estimate use value for them. Similarly, although current anglers and boaters will enjoy these activities more as a result of the control measures, we had no basis of estimating the resulting increase in consumer surplus to these users. Finally, no increases in boating could be assumed; this is due to current access limitations. The estimate of use value used in the benefit-cost assessment may therefore underestimate the actual total.

5.3 Linkage Uncertainties

A number of linkages between proposed remedial and mitigative measures, future activities, and benefits are not clear. The following linkages were still in question:

5.3.1 - Harbour Uses

Although estimates were developed on potential pike and bass populations yielded by each measure, it was not clear what effect the measures would have on other fish species.

Intuitively, the participation in fishing should be greater if an edible fishery is created rather than merely a sustainable fishery. However, the extent of an increase in demand in an edible fishery compared to a sustainable fishery is not known and cannot be estimated given the present body of data on the subject.

Remedial measures to improve water clarity and appearance and shoreline aesthetics should have some effect on demand for boating opportunities. However, access to the Harbour and will continue to be the lay factor limiting use. Any increases in demand created by improved water quality will not be realized because of the severe access limitation.

5.3.2 - Remedial and Mitigative Measures

The sequence of remedial and mitigative measures could be changed thus changing their effectiveness and amortization costs.

The effect of remedial options (source control) and mitigating measures (e.g., sediment control) can only be guessed at. For some mitigating measures, such as the chemical tank of sediments, it is difficult to forecast the biophysical response because the chemical mechanisms and biological controlling release from the sediments are not yet written or well understood.

5.3.3 - Benefit-Cost Framework

Non-Use Values

- There is little information on how to transfer the results of other studies - that is, how to tailor the results of other studies for application to another situation.
- Questions remain as to how non-use values will change over time. For example, if an individual is willing to pay $100 per year for a given change in water quality, is it clear that he will continue to be willing to pay this amount (in constant dollar terms) over, say, a twenty-year period.

Estimates of New Fishing Activities

The linkage between fish yield and fishing activity is not clear. An aspect of this linkage is the variation in new fishing activity according to whether the fish are edible or not.

Use Values

We had no basis upon which to estimate the increase in use value to current users from improved boating and fishing conditions. Although the study done by DPA Group for the Ministry of the Environment in May, 1987 suggests a method for estimating the increase in consumer surplus for boating and fishing from improved water quality, it does so on the basis of measurements of water quality different from those used in Phase 3 of this study. Specifically, changes in fishing use values were linked to changes in the amount of phosphorus and the resulting change in the morphoedaphic index; changes in use value from boating were linked to changes in chlorophyll a concentrations.

5.4 Assumptions

5.4.1 - Harbour Uses

In estimating present participation in recreational activities on Hamilton Harbour, the following assumptions were made:

- Recreational Boating for ships and mornings
    - turnover rate of 1
    - 3.5 persons per boat
    - average frequency of participation 7 times per season

  For Ramps
    - 25 boats launched per day
    - 2.5 persons per boat
    - slason length of 120 days
    - institutional constraint of 0.5

  Programs
    - Y Sailing School participants average 12 sessions per year

- Fishing
    - most observations were for the number of participants on a summer weekend so the number of observed participants was multiplied by 11 summer weekends to estimate participation
    - for coldwater specials, the number of ..... participants who multiplied by the number of spring weekend days (8)

- Outdoor Education and Nature Interpretation
    - in estimating participation in the Junior Naturalists Program, it was assumed that individuals participated twice per month
- For participation by the Hamilton Naturalists, it was assumed that the average number of participants reported in interviews was constant for all of the Club's outings.

In estimating future potential participation, the following assumptions were made:

- Recreational Boating
    - The estimate for the number of potential boaters in the future assumes that the percentage of residents who participate in boating will be the same as in the 1977 Ontario Recreation Survey (ORS).
- Fishing
    - Estimates of future fishing opportunities used a survey of urban anglers and household survey in Toronto as a surrogate model. Although a comparison of demographic characteristics, resources and trends in Hamilton and Toronto was not used to compare the two populations, it was assumed that the socio-economic characteristics and the type of urban fishing in the two cities are similar enough for the Toronto figures to be compared to Toronto. The frequency of use was estimated at 16 times per year. This compares to estimates derived from other fishing surveys.

5.4.2 - Remedial and Mitigative Measures

- Fisheries Aspects
    - A reasonable hypothesis of fisheries response to remedial measures and mitigating measures have been formulated for the fisheries.
- Eutrophication Aspects
    - The modelling tool combines available knowledge and hence provides an excellent first cut at calculating the Harbour's response.

- The DO calculations of response to control of point source reduction of ammonia and phosphorus are conservative, perhaps too conservative. The response tend to loading reductions is correct, but the magnitude may change by the order of 1-2 mg/L, dependent upon how the following integrate together:

  1) the updating of the eutrophication model with the work of Klapwiyk and Poulton and the formulation of a time response model for SOD;

  2) the use of an average seasonal calculation, rather than an extreme value for assessing hypolimnetic DO; and

- The general trend of water clarity is appropriate; the absolute magnitude may change by 10-40% with a reformulation of light clarity kinetics specific to the Harbour.

- The assumptions about swimming concerned CSO control and phosphorus disinfection of the two municipal effluents. The analysis did not include the following:

  - the lack of sufficient coverage of the harbour on a monitoring program to rigorously define the present state and to allow loading - harbour quality relationship to be evaluated;
  - the small frequency of overflows which still occur with storage; and
  - the bacterial contamination which results from stormwater flows in Red Hill Creek, Spencer Creek (into Cootes & into the Harbour), Chedoke Creek, and the Rambo-Hager Diversion. These concentrations are typically in the range of 10,000-20,000 mL F.C per 100 ml.

5.4.3 - Benefit-Cost Framework

The following assumptions were made in the benefit-cost assessment and the analysis of economic impact:

- General
  - all data are in 1987 terms

- Costs
  - assumes the amortization of capital costs over a 20-year period at a real discount rate of about 4%
- New Recreational Activity
  - increases in fishing activity are in response to increased yield of pike and bass only; no increase is estimated for potential additions to yield of other fish species.
  - assumes the mid-point of the range of new fishing activity estimated for each control measure (from Phase 2 report)
  - assumes no increase in recreational boating in response to control measures; this is due to access limitations
  - no increase in outdoor education and nature interpretation or other activities (due to lack of data)
  - increase in swimming activity (of 1.1 million user-days) assumes development of four beaches in the Hamilton/Burlington area and investments in curtains and water disinfection.
  - all new recreational activity is assumed to be generated by residents of the target area (the Regional Municipality of Hamilton-Wentworth and the City of Burlington)
- Use Value
  - consumer surplus for sportfishing was assumed to be $23 per angler day
  - consumer surplus for swimming was assumed at $5 per user day
  - no use value was estimated for increased enjoyment of boating, fishing and other recreational and educational activities by current users of the Harbour
  - no use value was estimated for new activities other than fishing and swimming

  - use values were not adjusted downward to reflect "diverted" as opposed to new fishing and swimming activity

- Non-Use Value
  - assumes that non-use value is generated only after improvements are made in the quality of the water in Hamilton Harbour - that is, non-use value through implementation of measure 6 Prime is assumed to be zero
  - assumes non-use value of zero for measure 7 as well, due to lack of data upon which to base estimate
  - assumes intrinsic value of $100 per household per year after implementation of measure 8

- Economic Impacts
  - estimation of economic impacts associated with expenditures incurred in implementing the control measures is made on the basis of an income multiplier of 0.9 and assumes the creation of 10 person-years of employment per $1,000,000 of directed expenditure
  - estimation of economic impacts associated with expenditures made as a result of increased fishing activity assures (a) that such expenditures will not exceed $100 per angler, (b) an income multiplier of 1.0, and (c) that 35 person-years of employment are created for every $1,000,000 of direct expenditure

5.5 Sensitivity Analysis

5.5.1 - Sensitivity of Study Results to Estimates of Diffuse Source Loading Control

The cost of remedial action for diffuse sources and its effectiveness can be assessed provided the loads can be estimated, the effectiveness of control evaluated, and the cost of control characterized.

Diffuse source loads constitute the dominant proportion of estimated phosphorus input levels to the harbour after implementation of sand filters combined sewer overflow control. Control measure 8 of the overall euthrophication scenario assumed that best management practices on approximately 50% of the watershed at a cost of $25 per acre year to the farmer. The area farming involved was assumed, in the absence of more definitive data. More recent data has been obtained which allows testing of this assumption.

Source of Diffuse Load Estimates

The estimates diffuse source loads for 1977 covered all sources and were as follows:

Watershed	Drainage Area (ha)	Flow (m^3/d)	Loading (kg/d)	TP (mg/L)	Unit Load g/ha/d
Red Hill	6,900	83,400	67	0.8	9.7
Grindstone	7,900	82,700	29	0.35	3.7
Rambo Hager	3,900	23,600	0.7	0.03	0.2
Cootes	27,600	345,000	140	0.4	5.1

Recent estimates have updated these estimates but have not markedly changed them. For example, SWMM modelling of Red Hill Creek gave estimates of 62 kg/yr. but were based upon a lower flow rate (25,000 m3/day) representative of the summer and a higher average phosphorus concentration (2.3 mg/L). The SWMM modelling was extended to other sewer systems, and was based upon the following:

Source	Total Phosphorus Concentration
Downtown combined sewer overflow	2.5 mg/L
Chedoke Creek	1.5 mg/L
Storm sewers in Hamilton West	1.1 mg/L

The assessment of the effects of control of diffuse sources upon loadings requires that both loads from urban and agricultural areas be assessed, that flow rates and average concentrations be known. This is difficult due to lack of sufficient monitoring data. The 1977 estimates are plausible. Other monitoring data for Red Hill Creek indicate similar values for total phosphorus in the early 1970's (.4 to 2.1 mg/L). The loadings for Cootes were based upon summer measurements of total phosphorus in the East Pond; the values for late winter are not know.

Magnitude of Diffuse Source Loads from Agriculture

Assuming that Hamilton Wentworth is representative of the whole watersheds, the following are the relative magnitude of crops:

Total Land Area	59,000	ha
Total Crops	43,000	ha
Grains	11,700	ha
Corn	12,000	ha
Hay	10,000	ha
Soy Bean	2,100	ha
Potatoes	690	ha
Vegetables	2,070	ha
Other Crops	3,000	ha

The crop area compares to the following areas of the Hamilton Harbour Watershed (estimated by planimetring from the map showing the extent of the urban in 1977) as follows:

Spencer's Creek (Non-urban Burlington)	349	km^2
Upper Hamilton (Non-urban)	46	
Dundas (Urban)	3.1	
Ancaster (Urban)	7	
Hamilton (Urban)	67	
Burlington (Urban)	16	

This summary indicates that certain areas constitute less than 20% of the total watershed in 1977; if it is assumed that the total area of upper Hamilton urbanizes (as it presently is doing) the total urban area is less than 30% of the total catchment.

Applying the Hamilton Wentworth crop ratio to the watershed area of 375 km^2 indicates that crops involving corn, soybean, potatoes and vegetables would constitute 17,000 ha.

Inclusion of grains would constitute 28,600 ha. Accordingly for the no-tillage option to be applicable to 25,000 ha (as assumed above), it must apply to both corn and grains.

Whether the reduction of 50 kg/day could be achieved is a question that needs addressing. The largest reduction in diffuse load would be achieved for a change in tillage practice for corn. The reduction of 5 kg/d represents a decrease of 20% from diffuse source loads. This could require complete elimination in loads from corn crops to zero export, and implausible task. Alternatively this reduction could be achieved from corn and other similar row crops. However, on a basin wide basin, achievement of a 20% reduction should be achievable.

Cost Estimates

Whether the cost estimates for diffuse source control ($1.5 million/year) are appropriate also requires further investigation. These two sources of error are:

i) the cost estimates are too high; and
ii) other costs, not included in the cost, need to be included.

The costs are based upon the maximum estimates made for the Bay of Quinte RAP in which the net farm cost of implementation of no tillage was assessed as $60/ha/year. Other costs estimates available from the literature suggested costs ranging from negligible to $75/ha/yr. If the net on farm impact were say $10/ha/yr. the net cost of diffuse source control would be $0.25 million/year rather than 1.5 million/year for consideration on the economic evaluation. This represents a large on-farm cost, but in terms of the assessment of the overall RAP, it represents a much smaller effect upon the analyses because the cost of diffuse control represents less than 10% of costs of all options to and including CSO control.

Other costs which need to be considered are the cost of urban control including storm ponds. It is difficult to place a cost estimate on this item until the magnitude of diffuse source inputs from urban areas are separated from those from agricultural areas. It is expected that Red Hill Creek loadings would be due mainly to urban areas, while Cootes loadings may or may not be due mainly to agricultural areas. The phosphorus budget for Cootes Paradise requires further assessment. Based upon 1977 data and the estimates of Robinson et. al., 1981, the following budget results:

1.	Dundas STP (1977 estimates)	18 kg/d

2.	Chedoke Creek (1981 estimates)	23 kg/d
3.	Spencers Creek (0.35 mg/L)	112 kg/d
	Total	153 kg/d

This closes to within 10% of the estimates made for the discharge from Cootes Paradise to Hamilton Harbour in 1977. Other estimates suggest that, in the early 1970's the Dundas Sewage Treatment Plant was loading 50 to 80% of the total load to Cootes Paradise. Furthermore, the value for Spencer's Creek assumes 0.35 mg/L total phosphorus, whereas historical data suggests values ranging from 0.2 to 0.8 mg/L with most of the data being in the 0.11 to 0.2 mg/L range.

5.5.2 - Benefit-Cost Framework

The following sensitivity analysis describes the results obtained by varying some of the key assumptions used in the benefit-cost assessment presented in the Phase 4 report. Net benefits are calculated for three sequences of control measures - measures 1 through 6 Prime, 7 and 8 as numbered in Table 4-1 - and compared against the net benefits reported for each of these sequences in Table 4-7. The analysis is based on variation of three key factors:

1. Estimates of non-use values.
2. Use estimates - specifically, number of angler days and number of user-days for swimming.
3. Time horizon used for converting capital costs into annual values.

The results of these three analyses are described separately below.

Non-Use Values

Non-use values were chosen for analysis because they are the major determinant of net benefits. As estimated in the Phase 4 report, they outweigh the only other significant component of economic value - use value from swimming - by a factor of 4. Furthermore, they are independent of "use" estimates, i.e., estimates of new fishing and swimming activity.

Although there is a range of fishing use value estimates as well, - from approximately $6 to $40 per angler-day - the range yields economic value which, even at the upper limit, is insignificant compared to non-use values. The analysis is therefore confined to non-use values.

The results, shown in Table 5.1, are based on non-use values as follows:

- For implementation of measures 1-6 Prime, a "low" non-use value of zero and a "high" estimate of $10 per household per year.
- For implementation of measures 1-7 and 1-8, a low of $10 and a high of $150 per household per year.

The estimates contained in the Phase 4 report are based on a non-use value of zero until measure 8 is implemented whereupon a value of $100 per household per year is assumed. The range of non-use values in the literature is such that all these values - $10, $100, and $150 are supportable.

The conclusion from this analysis is that depending on the amount chosen as the basis for calculating non-use values, the resulting net benefits can be extremely large - or, they an be negative.

Use Estimates

Fishing

The Phase 2 estimates of new recreational activity resulting from implementation of the control measures were stated in terms of a range for new angler days. Estimates of economic value in the Phase 4 report take, as their basis, the mid-point of this range. However, the estimates of new activity are based only on the yield of Northern Pike and Largemouth Bass and do not take into account the increases in other species which may result from the control measures. Table 5-2, below, shows what net benefits would be if the upper limit in the Phase 2 report based only on Northern Pike and Largemouth Bass were doubled as a measure of the possible increase which might take place in other species.

As shown in Table 5-2, if the upper limit of new fishing activity, estimated in the Phase 2 report, is doubled, the net benefits become positive for measure 6 Prime. The results for measures 7 and 8 are essentially unchanged, because of the relative size of the costs, for measure 7, and of non-use and swimming values, for measure 8.

TABLE 5.1

RESULTS GIVEN VARIATION IN NON-USE VALUES
(000'S OF CUMULATIVE 1987 DOLLARS PER YEAR)

Control Measure	Use Value*	Non-Use Value		Total Economic Value		Costs	Net Benefits		Estimate In Phase 4 Report
		Low	High	Low	High		Low	High	
Effect of light on measures 1-6 (6 Prime)	120	0	1,960	120	2,080	330	(210)	1,750	(206)
Sand Filters in STP (7)	130	1960	29,400	2,090	29,530	6,500	(4,410)	23,030	(6,370)
CSO Control (8)	5,630	1960	29,400	7,590	35,030	12,800**	(5,210)	22,230	12,430

* For fishing and swimming combined.

** Includes cost of beach development and curtains/disinfection.

TABLE 5.2

RESULTS GIVEN DOUBLING OF NEW FISHING ACTIVITY (000'S OF CUMULATIVE 1987 DOLLARS PER YEAR)

Control Measure	Use Value		Non-Use Value	Total Economic Value	Costs	Net Benefits	Estimates in Report
	Fishing	Swimming					
Effect of light on measures 1-6(6 Prime)	$420	$ 0	$ 0	$420	$330	$ 90	($206)
Sand Filters in STP (7)	$420	$ 0	$ 0	$420	$6,500	($6,080)	($6,370)
CSO Control (8)	$430	$5,500	$19,600	$25,530	$12,800	$12,730	$12,430

Swimming

The Phase 2 report estimates that approximately 1.1 million user days of swimming will be generated if all nine control measures are implemented, assuming the development of four new beaches in the Harbour. If this estimate is arbitrarily cut in half, net benefits from implementing all nine measures are reduced to $9.7 million per year, versus the report estimate of $12.4. (Swimming is not possible before the implementation of measure 8.)

Time Horizon for Amortizing Capital Costs

Estimates in the Phase 4 report are framed in terms of values in a typical year. This is straight forward in the case of operation and maintenance costs and in the case of benefits, all of which are expected to remain fairly constant on an annual basis. Capital costs, however, are one-time expenditures. If they are spread over a 20-year period, as was done in the Phase 4 report, the resulting annual values are considerably lower than if they are amortized over a 10-year period - as a measure of a shorter "life" for the capital equipment involved or as a proxy for under-estimation of nominal capital costs. The results of amortizing capital costs over 10 years are shown in Table 5-3.

The results in Table 5-3 suggest that if the capital costs are considerably greater than those estimated in the Phase 3 report, or if they are spread over a 10-year as opposed

TABLE 5.3

RESULTS GIVEN AMORTIZATION OF CAPITAL COSTS OVER 10 YEARS (000'S OF CUMULATIVE 1987 DOLLARS PER YEAR)

Control Measure	Benefits	Costs	Net Benefits	Estimates in Report
Effect of light on measures 1-6 (6 Prime)	$120	$490	($370)	($206)
Sand Filters in STP (7)	$130	$9,590	($9,460)	($6,370)
CSO Control (8)	$25,230	$19,570	$5,660	$12,430

to a 20-year span, the magnitude of the net benefits resulting from implementation of all nine control measures is reduced. Otherwise, the results are essentially unchanged.

5.6 Recommendations

5.6.1 - Harbour Uses

- Gaps in information on recreational activities in Hamilton Harbour could be solved by implementing household and user surveys in the study area. The surveys would have to be carefully designed to measure present and future demand for Harbour activities and produce data which is in the format required by the benefit cost mode.

- Fishing information gaps could easily be solved using existing programs. The Ontario Ministry of Natural Resources currently undertakes creel surveys and household surveys (Ontario Angler Survey) to estimate fish yields and angling activity. These existing programs could include Hamilton Harbour as a location and this provides the required information.

5.6.2 - Remedial and Mitigative Measures

- For construction of cost abatement curves, the background data that was used to generate the pollutant loadings should be investigated and assessed in terms of reduction and treatment costs in more detail. The information gained would be valuable in generating cost curves.

5.6.3 - Biophysical Response of the Harbour

- Additional monitoring data are needed for:

  a) point sources for heavy metals, PAH, PCB, other organics, pathogenic bacteria, etc.

  b) non-point source pollutants such as combined sewer overflows and agricultural runoff for heavy metals PAH, PCB, other organics, pathogenic bacteria, etc.

- Additional research on the contribution and effects of contaminated sediments on the water column, fish and biota.

- Additional physical data to scale physical limnological measurements to transport coefficients.

Eutrophication Aspects

The eutrophication model used for calculations of biophysical response of Hamilton Harbour to remedial and mitigative measures needs updating with additional/allied set of models and validation test carried for the period 1978-1987. Additional modifications would include further horizontal compartization of the harbour to provide increased realism and credibility to the modelling efforts.

The dissolved oxygen calculations of response to control of point source reduction of ammonia and phosphorus are conservative, perhaps too conservative. The response trend to loading reductions is correct, but the magnitude may change by the order of 1-2 mg/L, dependent upon how the following integrate together:

1) the updating of the eutrophication model with the work of Klapwiyk and Poulton and the formulation of a time response model for sediment oxygen demand;

2) the use of an average seasonal calculation, rather than an extreme value for assessing hypollmnetic dissolved oxygen; and

The general trend of water clarity is appropriate; the absolute magnitude may change by 10-40% with a reformulation of light clarity kinetics specific to the Harbour.

5.6.4 - Benefit Cost Framework

- The set of control measures proposed for creation of a warm-water fishery in Hamilton Harbour involve substantial expenditures. According to the benefit-cost framework outlined in Phase 4, positive net benefits result only on the basis of the intrinsic benefits which will accrue to residents of the area from cleaner water in the Harbour. Estimation of these benefits was based on a review of the literature. Given time and budget limitations, the review was not exhaustive. However, even if it had been, it is not clear that results from one study or group of studies can be applied to the situation specific to Hamilton Harbour. Thus, it is our recommendation that the Phase 4 results be interpreted as a preliminary assessment and that, prior to implementing the remedial measures, a survey be carried out of residents in the target area in order to refine the benefit estimates. A survey would allow the collection of primary data tailored to the current and proposed conditions for Hamilton Harbour and could provide a clearer indication of how much weight to place on estimates of non-use benefits versus use values.

- As noted above, estimates of non-use value were based on a review of the literature. Although this review encompassed much of the research which has been done on intrinsic values, it was not exhaustive. A literature review will be a facet of all the Remedial Action Plan Assessments undertaken by the Ministry. Furthermore, it involves a complex area of research with a steep "learning curve". Thus, we recommend that the Ministry undertake a one-time literature review which is exhaustive, thorough, and usable by all those involved in the RAP Assessments.

6.0 CONCLUSIONS

Implementation of the mitigative and remedial measures identified as being most cost-effective in promoting a self-sustaining warm water fishery in Hamilton Harbour, will result in net economic benefits of approximately $12.4 million if all nine measures are adopted. This estimate is highly dependent on estimates of the non-use, or intrinsic, value associated with improving water quality in the Harbour. The estimate used in this analysis -- of $100 per household after implementation of all control measures -- was derived from a review of the literature and it is not known how accurately it reflects the particular circumstances of this study. The results of the benefit-cost assessment should therefore be regarded as preliminary. The proposed control measures entail a significant financial investment and, as such, warrant more refined supporting data upon which to base their implementation. Such data could be obtained by conducting a survey of residents in the Hamilton area to determine their assessment of the non-use, and use, benefits associated with improved conditions in the Harbour.

A primary survey would also permit a more complete assessment of certain aspects which the current study was unable to incorporate fully, if at all. These include:

- Estimation of the use value associated with activities other than swimming and fishing which would result from, or be enhanced by, the proposed control measures.
- Differentiation of use values associated with fishing for edible vs. non-edible fish.
- Assessment of how uses of the Harbour, and the associated use value, will evolve over time.
- A better understanding of how non-use values will change over time.

Benefit-cost analysis is a complex procedure and this is particularly true in a recreational application where techniques are relatively new and untried. Furthermore, this study has been largely exploratory in nature and does not constitute an exhaustive analysis. Although preliminary, however, the results do suggest an economic basis for improving water conditions in Hamilton Harbour given patterns of use predicted for the short-term. As current constraints and limitations to use of the

Harbour (such as the current shortage of boating facilities) are reduced -- as would likely be the case over the medium- to long-term - the net economic benefits will increase.